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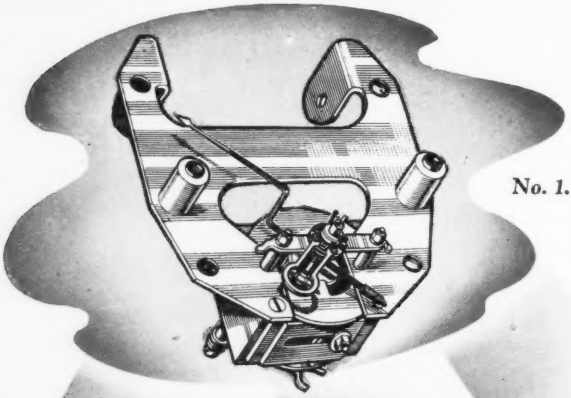
SEVEN SHILLINGS
AND SIXPENCE

The Journal of THE ROYAL AERONAUTICAL SOCIETY

FEATURES OF WESTON AIRCRAFT INSTRUMENTS



No. 1. Moving Element Assembly

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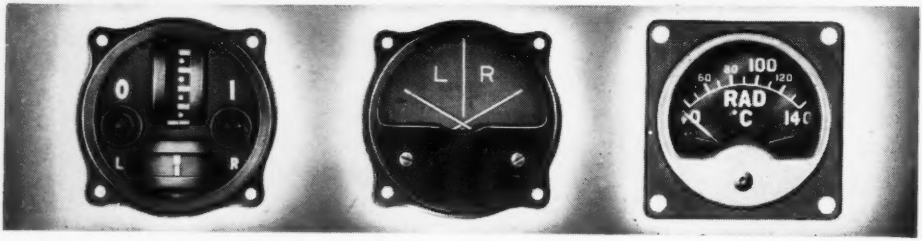

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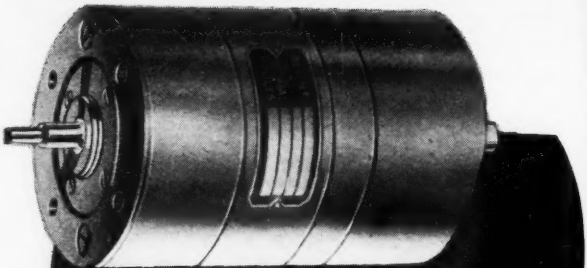

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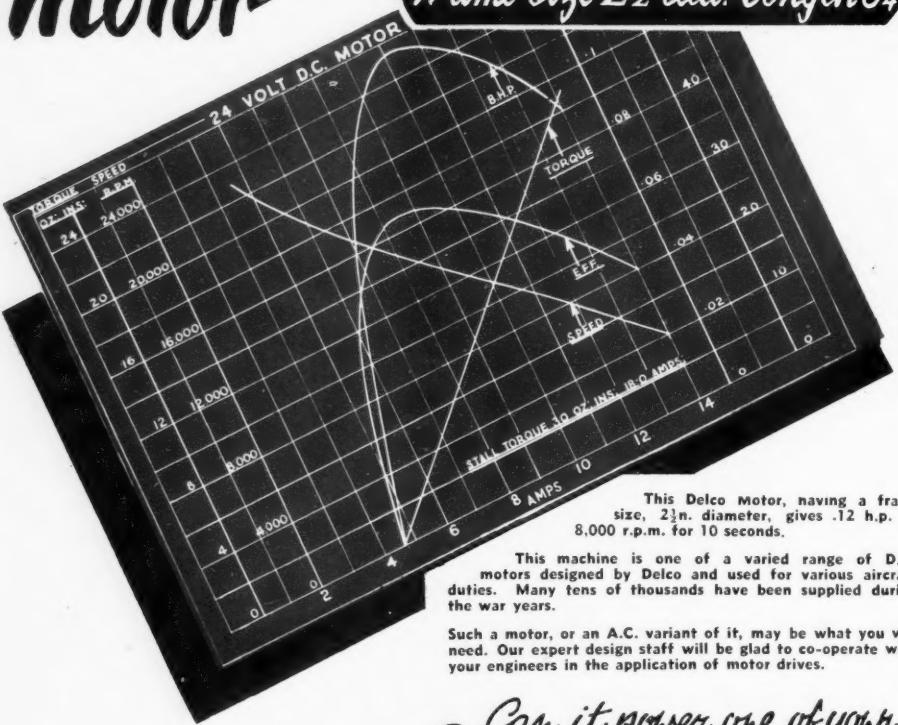

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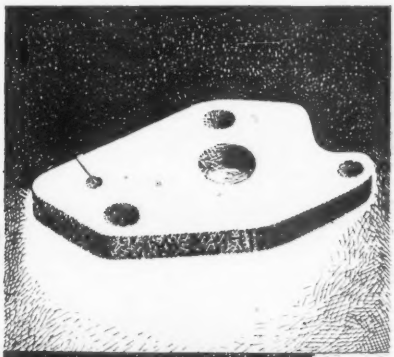

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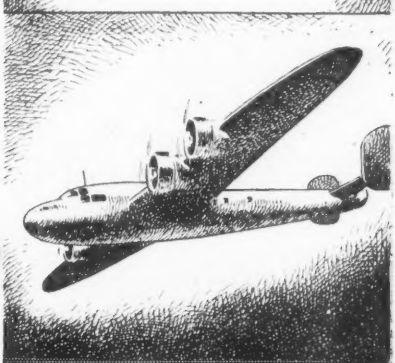

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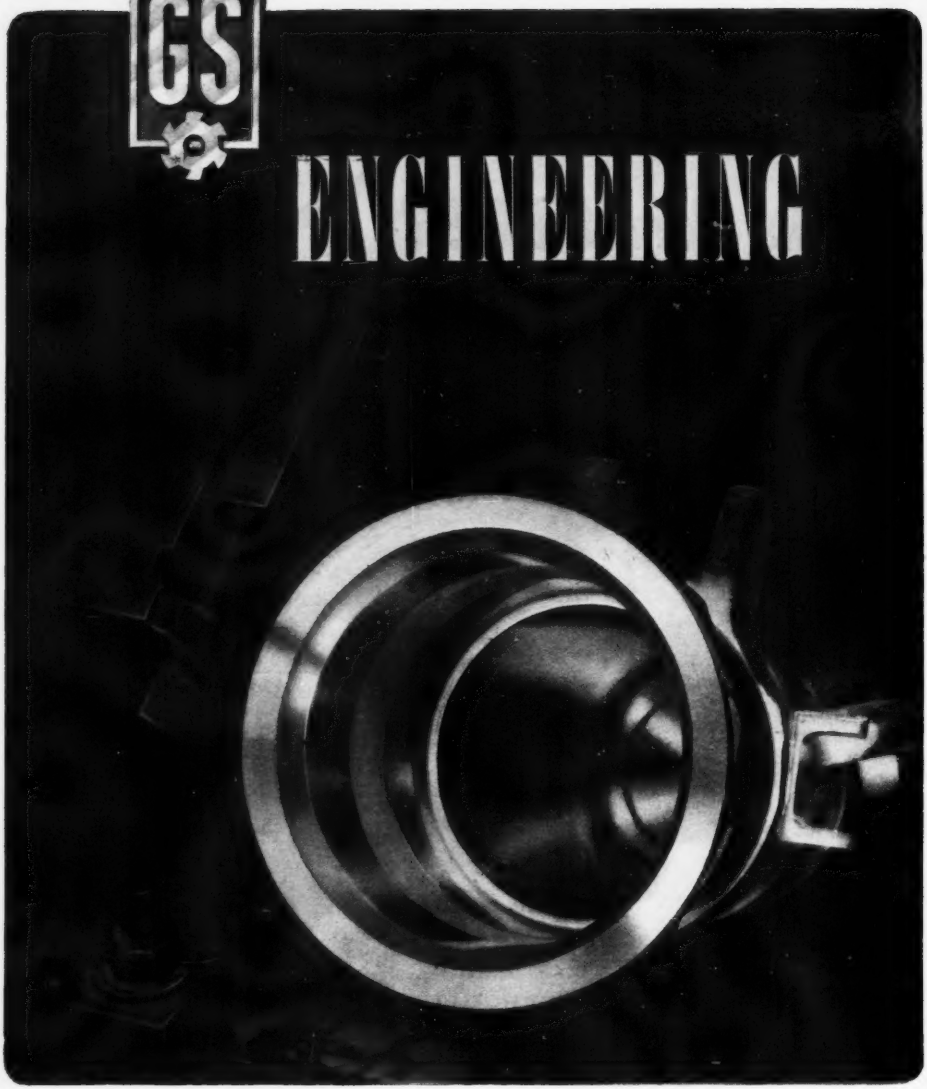

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The Society offers a number of valuable prizes, most of them annually. Full particulars of the conditions attaching to the awards of these prizes may be obtained on application

Society's Gold Medal

This is the highest honour which the Society can confer for work of an outstanding or fundamental nature in aeronautics.

British Gold Medal for Aeronautics

The British Gold Medal for Aeronautics is awarded for an achievement leading to advancement in aeronautical science.

Simms Gold Medal

The Simms Gold Medal is awarded annually for the best paper read in any year before the Society on any science allied to aeronautics, e.g., meteorology, wireless telegraphy, instruments.

The George Taylor (of Australia) Gold Medal

The Taylor Gold Medal is awarded annually, at the discretion of the Council, for the most valuable paper submitted or read during the previous session.

Wakefield Gold Medal

The Wakefield Gold Medal is awarded annually to the designer of any invention or apparatus tending towards safety in flying, and is open to members or non-members.

Society's Silver Medal

The Society's Silver Medal is awarded, at the discretion of the Council, for some advance in aeronautical design.

British Silver Medal for Aeronautics

The British Silver Medal for Aeronautics is awarded for an achievement leading to advancement in aeronautical science.

Society's Bronze Medal

The Society's Bronze Medal is awarded, at the discretion of the Council, under the same conditions as those for the Silver Medal, but for some less important advance in aeronautical design.

Wilbur Wright Memorial Premium

The Wilbur Wright Memorial Lecture is held annually, a premium of fifty pounds being awarded to the lecturer invited by the Council to deliver the lecture. The lecture is usually given alternately by an American and an Englishman, and is the most important aeronautical lecture of the year. It is delivered whenever possible, on the last Thursday in May of each year.

British Empire Lecture

The Council of the Royal Aeronautical Society have completed the arrangements for the founding of a British Empire Lecture.

The lecture, on any aeronautical subject approved by the Council, will be delivered annually in September in London, by a lecturer, chosen in alternate years from the British Dominions and Colonies and Great Britain.

The Council, by founding this British

Empire Lecture, are anxious to encourage new ideas and new points of view from all parts of the British Empire, and to make the Lecture second only in importance to the Wilbur Wright Memorial Lecture.

The British Empire Lecture will have a premium of £50 attached to it, and in the case of lecturers coming from the Dominions and Colonies an allowance up to £100 will be paid towards the Lecturer's expenses.

It is proposed to hold the first lecture in September, 1945, and suggestions for lecturers should be received by May 31st, 1945, at the latest.

R.38 Memorial Prize

The R.38 Memorial Prize is offered annually for the best paper received by the Society on some subject of a technical nature in the science of aeronautics, preference being given to papers which relate to airships. The prize is twenty-five guineas.

The Herbert Akroyd Stuart Lectures

Under the will of the late Mr. Herbert Akroyd Stuart a sum of £700 is held in trust by the Society for the offer of a prize every two years, for the best paper or lecture read or given before the Society dealing with the Origin and Development of Heavy-oil Aero Engines. The prize is open to members and non-members.

Edward Busk Memorial Prize

The Edward Busk Memorial Prize is offered annually for the best paper received by the Society on some subject of a technical nature in connection with aeroplanes (including seaplanes). Its value is twenty guineas.

Pilcher Memorial Prize

The Pilcher Memorial Prize is offered annually, at the discretion of the Council, for the best paper by a Student on heavier-than-air craft or any analogous subject. Its value is five guineas.

Usborne Prize

The Usborne Prize is offered annually, at the discretion of the Council, for the best paper by a Student on some subject in connection with Aero Engines. Its value is five guineas.

Major Baden-Powell Memorial Prize

The Major Baden-Powell Memorial Prize is awarded in May and December of each year to the student who is considered the best student by the examiners in the Society's Association Fellowship examinations. Its value is three guineas.

Elliott Memorial Prize

The Elliott Memorial Prize is awarded twice yearly to the apprentice at Halton who has the highest percentage of marks in the passing-out examination. Its value is $2\frac{1}{2}$ guineas for each award.

R. P. Alston Memorial Prize

The R. P. Alston Memorial Prize is awarded to any Graduate or Student of the Society for work done leading to improvement in the safety of aircraft, and particularly for improvement in stability and control. Its value is approximately £5.

Branch Prize

The Council offer an annual prize of twenty guineas for the best paper read before the Branches during the previous lecture Session. The prize is open to any member of the Society or of any Branch.

Journal Premium Awards

The Council has set aside an annual sum of £250 to be given as premium awards to authors of papers published in the Journal.

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THE JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY

With which is incorporated The Institution of Aeronautical Engineers

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The Journal of The Royal Aeronautical Society was founded in 1897 in succession to the Annual Reports. For the opinions expressed in Papers that are signed or initialled the authors alone are responsible. None of the papers or paragraphs must be taken as expressing the opinion of the Council of The Royal Aeronautical Society unless such is definitely stated to be the case. **The Journal is published monthly at the Offices of the Society, 4, Hamilton Place, Piccadilly, London, W.1.** Subscriptions per annum, £4 10 0 post free; Single Numbers 7/6 or 7/9 post free. All communications for publication in the Journal, or on general matters affecting the Society should be addressed to—The Secretary, J. Laurence Pritchard, 4, Hamilton Place, W.1. The Society's Bankers are Messrs. Coutts and Co. All communications respecting Advertisement matters should be addressed to—The Advertisement Manager, Journal of The Royal Aeronautical Society, 4, Hamilton Place, W.1.
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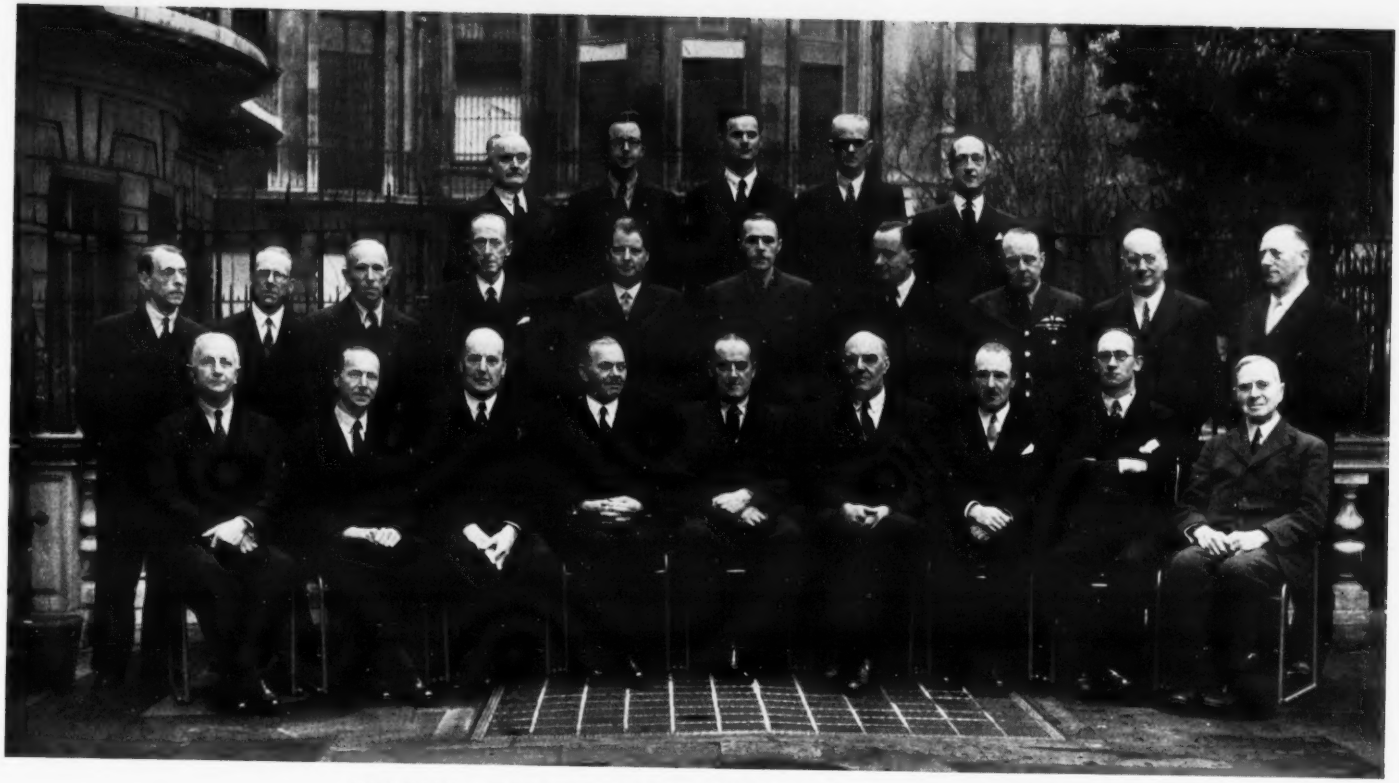

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FEBRUARY NOTICES 1945

JOURNAL PREMIUM AWARDS

The Council have set aside an annual sum of £250 for the award of premiums for papers published in the *Journal* and the Council hope that members will contribute papers on their own special subjects.

Annual General Meeting

Notice is hereby given that the Annual General Meeting of the Royal Aeronautical Society, with which is incorporated the Institution of Aeronautical Engineers, will be held on Thursday, March 29th, 1945, at 5.30 p.m., in the Offices of the Society, 4 Hamilton Place, London, W.1.

AGENDA

1. To read the Notice convening the Meeting.
2. To receive and deliberate upon the Report of the Council on the state of the Society and the Balance Sheets of Aerial Science Limited and Aeronautical Trusts Limited for the year ended 31st December, 1944.
3. To receive the nominations for Council for the years 1945-46.
4. To announce the List of Fellows elected by the Council in accordance with Rule 4.
5. To elect the Auditors for the ensuing year for Aerial Science Limited and Aeronautical Trusts Limited.
6. Any other business.

By order of the Council,
J. LAURENCE PRITCHARD,
Secretary.

Light refreshments will be served after the meeting.

Debate on Civil Aviation

The Debate on Civil Aviation on Tuesday, March 13th, 1945, will be on the following motion: "That in the opinion of this meeting, speed in air transport is more important than comfort." The debate will be held at 5.30 p.m. in the Lecture Hall of the Institution of Mechanical Engineers, Storey's Gate, S.W.1.

Premium Awards

Particular attention has been drawn above to the award of premiums for the most meritorious papers published in the JOURNAL. It is hoped that these awards will encourage members to write for the JOURNAL. The Editor will gladly welcome any suggestions for papers, and it would add considerably to the values of the suggestions if the names of suitable authors could be made at the same time.

New Year's Honours

K.B.

R. H. Dobson, C.B.E., Fellow.
A. F. Sidgreaves, O.B.E., Companion.
W. P. Hildred, C.B., O.B.E., M.A., Companion.

C.B.

Air Vice Marshal A. Ferrier, M.C., B.Sc., D.I.C., Associate Fellow.

C.B.E.

A/Cmdre. G. E. Wait, B.A.Sc., D.I.C., Associate Fellow.

O.B.E.

S/Ldr. W. R. Baird, Associate Fellow.
S/Ldr. H. T. Grigg, Associate Fellow.
W/Cmdr. E. A. Harrop, Associate Fellow.
W/Cmdr. R. M. Hayes, Associate.
W/Cmdr. H. C. Witts, Associate Fellow.

Second Row: Captain J. L. Pritchard (Secretary), Mr. A. C. Brown, Mr. C. C. Walker, Sir Francis Shelmerdine, Major F. B. Halford, Mr. S. H. Evans, Mr. G. H. Dowty, Air Commodore F. R. Banks, Mr. A. N. D. Smith (Honorary Accountant), Captain A. C. Lamplugh (Honorary Treasurer).
Back Row: Mr. A. G. Elliott, Mr. E. J. N. Archbold, Mr. R. S. Stafford, Mr. G. E. Petty, Mr. L. A. Wingfield (Solicitor).
Absent: Mr. W. C. Devereux (Vice-President), Mr. S. Camm, Mr. N. S. Muir, Mr. A. E. Russell, Mr. J. E. Hodgson (Hon. Librarian).

Increase in Price of Journal

The Council have decided that as from January 1st, 1945, the price of the JOURNAL should be increased to 7s. 6d. per issue to non-members (£4 10s. per annum).

Election of Council

Attention is drawn to the following Rules for election of Council. Nominations should be received by March 3rd, 1945. Nomination forms may be obtained from the Secretary. Attention is drawn to possible delays in the post at the present time. Nomination forms may be signed by any members of the Society excepting Honorary Fellows, Graduates and Students.

Rule 17.—One-half of the Council (excluding the President and the immediate Past-President if a Member of Council) shall retire annually. The members who shall retire shall be those longest in office, except as provided in Rule 77. Retiring Members of Council who have served for two terms in succession (four years) shall not be eligible for re-election until the next annual election, when they will be eligible.

Rule 72.—The composition of the Council shall be as follows:—

(*a*) Not less than sixteen shall be elected from the technical or scientific grades of the R.Ae.S.—that is to say, from among the Fellows, Associate Fellows and Associates.

(*b*) Of these sixteen, four at least shall be Fellows.

Rule 73.—Nominations of candidates for election to the Council must be received by the Secretary not less than twenty-one days before the Annual General Meeting, with an intimation in writing by the candidates that they are willing to serve. Nominations must be signed by one supporter and two seconders, who must be each entitled to vote in the R.Ae.S.

Annual Subscriptions of Members

Members are reminded that their 1945 subscriptions became due on January 1st, 1945.

The Council are very grateful to all those members who have offered to forego their JOURNALS for the duration of the war . The same reductions will be made to the 1945 subscriptions of these members as applied to the 1944 subscriptions. Subscriptions of Fellows, Associate Fellows, Graduates, Companions and Founder Members who have given up their JOURNALS will therefore be reduced by 10s. 6d. Associates will receive the reduction already laid down in the Rules. The low subscription at present paid by Students does not permit any reduction to be made.

The following will be the rates for 1945 therefore:—

	Home receiving Journal. £ s. d.	Home not receiving Journal. £ s. d.	Abroad receiving Journal. £ s. d.	Abroad not receiving Journal. £ s. d.
Founder Members	2 2 0	1 11 6	2 2 0	1 11 6
Fellows	4 4 0	3 13 6	3 3 0	2 12 6
Associate Fellows	3 3 0	2 12 6	2 2 0	1 11 6
Associates	2 2 0	1 1 0	2 2 0	1 1 0
Graduates (age 21-25)	2 2 0	1 11 6	2 2 0	1 11 6
,, (age 26-28)	2 12 6	2 2 0	2 12 6	2 2 0
Students	1 1 0	1 1 0	1 1 0	1 1 0
Companions	2 2 0	1 11 6	2 2 0	1 11 6

Election of Fellows

Attention is drawn to Rules 4 and 5, which read as follows:—

Rule 4.—Election to Fellowship will be made annually by the Council for announcement at the Annual General Meeting of the Society in March.

Rule 5.—Nomination (on Form A) for Fellowship must be received by March 1st each year at the latest, for consideration at the March Council Meeting.

Binding of Journals

Owing to increased costs, the prices of binding of all JOURNALS will be as follows:

1944 Volume	9s. 0d.
Previous Volumes	11s. 0d.
Library Catalogue bound separately (from 1941 Vol.)	10s. 0d.

JOURNALS for binding should be sent direct to The Lewes Press Limited, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the office of the Society.

Lectures 1945

The following programme of lectures has been arranged to be held, with the exception of the discussions on Civil Aviation, at 6.30 p.m. in the Lecture Hall of the Institution of Mechanical Engineers, Storey's Gate, St. James', S.W.1 (by permission of the Council of the Institution). Members do not need admission tickets, but visitors must obtain a ticket through a member.

Thursday, 15th February—Aircraft Wheels and Brakes. by Mr. J. Wright, A.F.R.Ae.S.

Tuesday, 20th February—The Importance of Power Unit Development, by Air Commodore F. R. Banks, F.R.Ae.S.

Thursday, 1st March—Control Surface Design, Joint Lecture by Mr. M. B. Morgan, M.A., A.F.R.Ae.S., and Mr. H. H. B. M. Thomas, B.Sc.

Thursday, 8th March—Electrics for Aircraft, by Mr. C. G. A. Woodford, A.F.R.Ae.S.

Tuesday, 13th March—Debate on Civil Aviation, at **5.30 p.m.**

Thursday, 22nd March—Hydraulics for Aircraft, by Mr. R. H. Bound, F.R.Ae.S.

Thursday, 5th April—Modern Experimental Work on Aeroplane Structures, by Dr. A. G. Pugsley, F.R.Ae.S.

Monday, 16th April—Debate on Civil Aviation.

Thursday, 31st May—33rd Wilbur Wright Memorial Lecture, by Mr. T. P. Wright, Hon.F.R.Ae.S.

Branch Lectures

MEDWAY BRANCH

Lectures are held at 7.15 p.m.

Monday, 12th February—Compressibility, by Dr. W. F. Hilton.

Monday, 12th March—Engine Installations, by Mr. F. Mayer.

Monday, 9th April—Work in an Experimental Seaplane Tank, by Mr. L. Smith.

BELFAST BRANCH

Lectures are held in the Central Hall, College of Technology, at 6.30 p.m.

Monday, 26th February—Production Control, by Mr R. Beaney, A.F.R.Ae.S., A.M.P.E.

Monday, 26th March—Inspection, by Mr. W. H. Bell, A.F.R.Ae.S.

Monday, 16th April—Test Flying, by Mr. J. Lankester Parker, F.R.Ae.S.

BRISTOL BRANCH

Lectures are held in the Conference Room, Bristol Aeroplane Company, Filton House, Bristol, at 6.30 p.m., by kind permission of the Directors.

Tuesday, 20th February—Flying Boats, by Mr. A. Gouge, F.R.Ae.S.

Tuesday, 6th March—Development in Rotating Wing Aircraft, by Mr. R. Hafner.

Tuesday, 20th March—Film Night and Annual General Meeting.

DERBY BRANCH

Lectures are held in the Rolls-Royce Welfare Hall, Nightingale Road.

5th March—Lecture by Mr. E. J. Earnshaw.

9th April—Lecture by Dr. S. G. Hooker.

7th May—Shock Waves at Sonic Speeds, by Dr. W. E. Hilton, B.Sc., A.R.S.C.

PORTSMOUTH BRANCH

Lectures are held in the Oddfellows Hall, Kingston Road, Portsmouth.

8th March—A.C. Electrical Equipment on Large Aircraft, by Mr. R. H. Woodhall, A.F.R.Ae.S.

22nd March—First Principles of Grinding, Film demonstration.

Graduates' and Students' Section

Thursday, March 15th, 7.30 p.m. Lecture by Mr. W. Tye, A.F.R.Ae.S., on "Airworthiness."

Wednesday, April 4th—Annual General Meeting of Section at 7.30 p.m. Representatives of groups outside London should make a special effort to attend this meeting.

Society of British Aircraft Constructors' Scholarships

The S.B.A.C. Scholarships are open to British subjects between the ages of 16 and 18 on the 1st September in the year of the award. They are designed for the assistance of young men who are unable, for financial reasons, to take up a course of education fitting them to become aircraft engineers. The general administration is carried out by the Royal Aeronautical Society and applications for entry forms should be addressed to 4 Hamilton Place, W.1. Entries for 1945 close on February 28th, 1945.

Election of Members

Associate Fellows

Dennis Stephen Bancroft (from Graduate), Arthur Frankish (from Student), Howard Giddings, John Hunter Lowden, John Kitchen Moakes (from Graduate), Harold Noden, Frederick William Page (from Graduate), Henry Charles Heald Peck.

Associates

Arthur Stuart Brockbank, John Charles Oswald Grunert (from Student), Alfred George Hayes, Terence Macrae Myles (from Student), Maurice Norman Neville, Herbert Thomas Nicholls, Harold Edward Ramshaw (from Student), Norman Clarence Strudwick, Lawrie Vincent Somerville.

Graduates

Francis Jeffrey Colville, Alan Greaves, Desmond Aylmore Kelly, Maurice George Marsh, William Henry Mayall (from Student), Francis William Morgan (from Student).

Students

Roland Dennis Ashborn, William Maurice Brady, Robert Arthur Bulloch, Graham George Caseley, John Samuel Caseley, Robert Anthony Chalmers, Leslie Freeguard, Alan Weeden Green, Stanley Peter Parnell Guy, Alfred Norman Kinkead, William Burns Petrie, Alan William Ratcliff, Michael George Trestrail, Desmond Gerald Turley, Anthony Roy Turley, Desmond Albert Thuryood, Peter Arthur Ward.

Acknowledgments

The Council acknowledge with grateful thanks the gift of books for the Library from Mr. A. W. Judge (Associate Fellow), and also a collection of handbooks and journals from Mr. J. V. Inglesby (Associate Fellow).

Additions to Library

Pamphlets in italics with location reference following in brackets.

Books marked * or ** may not be taken out on loan.

A.a.308.—Aerodynamics. L. R. Parkinson. Macmillan Co., New York, 1944. $2.25.

B.c.66.—*The Hamilcar Military Transport Glider.* (*Press release,* 14/12/44.) *Ministry of Aircraft Production.* (Y.3.iii.33.)

*B.g.142.—British Aircraft (Vol. 2). R. A. Saville-Sneath. Penguin Books Ltd., 1944. 5/-.

*D.a.H.9.—Poland's Possible Contribution to Future Air Transport. Polish Ministry of Industry, Commerce and Shipping. 1944. D.a.H.9. (Folio.)

D.b.227.—*Post-War Civil Aviation in India. Sir Frederick Tymms. Indian National Airways,* 1944. (*Reprint.*) (PD.1/29.)

**D.c.98.—*Airport Design* (*April 1st,* 1944). *Civil Aeronautics Administration. U.S. Dept. of Commerce,* 1944.

**D.c.99.—*Design of Airport Runways. War Dept.* (*Corps of Engineers*), *U.S. Army,* 1941.

E.d.23.—Junior Draughtsmanship (Vol. 1). J. T. Goddard and S. T. Saunders. Saunders-Roe Ltd. (Privately printed), 1944.

G.e.E.62.—*Steel Prices and Costs.* (*Extracts from the National Press.*) *British Iron and Steel Federation.* 1944. (PG.6/20.)

L.d.103.—From Atoms to Stars. Martin Davidson. Hutchinson & Co., 1944. 15/-.

L.j.92.—*Photogrammetry.* (*Lecture before Victorian Institute of Engineers,* 15/12/1937. *Eric Pyke.* (PL.2/8.)

*Q.a.152.—A Bibliography of Aviation Medicine: Supplement, 1944. P. M. Hoff, E. C. Hoff and J. F. Fulton. C. C. Thomas, Illinois. 1944. $2.50.

S.b.137.—Per Ardua. (Rise of British Air Power, 1911-1939.) H. St. George Saunders. Oxford University Press, 1944. 15/-.

*UU.b.28a.—*28th Annual Report of the National Advisory Committee for Aeronautics* (*Administrative Report only*). *N.A.C.A., Washington,* 1944.

A.a.309-10.—A Complete Course in Elementary Aerodynamics. N. A. V. Piercy. English Universities Press, 1944. 21/-.

A.c.16.—Applied Thermodynamics. Wm. Robinson and John M. Dickson. Sir Isaac Pitman & Sons, 1940. 20/-.

B.a.331.—Bombers of the Present War. Capt. Ellison Hawks. Read Photographs Co., 1944. 7/6.

B.a.332.—More Fighters of the Present War. Capt. Ellison Hawks. Real Photographs Co., 1944. 5/-.

D.d.21.—*Education and Training for Engineers* (*2nd Report*). *Post-War Planning Committee, Institution of Electrical Engineers,* 1944 (PE.2.b.14).

D.d.22 and 23.—*Your Future in Civil Aviation. Guild of Air Pilots and Navigators,* 1945. 1/- (PE.2.b.15 and 16) (2 copies).

**E.b.97-99.—Proceedings of the Society for Experimental Stress Analysis (U.S.A.). Vol. 1, No. 1; Vol. 1, No. 2; Vol. 2, No. 1. Addison-Wesley Press Inc., Cambridge (Mass.), 1943-44. $3, $4 and $5 respectively.

**E.b.100-101.—Proceedings of 15th and 16th Conferences of Eastern Photo-Elasticity Society (U.S.A.), June and November, 1942. Addison-Wesley Press Inc., Cambridge (Mass.), 1943. $1.50 each.

G.e.A.97.—Riveting of Wrought Aluminium Alloys. Bulletin of Wrought Light Alloys Development Association, 1944.

G.e.F.18.—*Practical Applications of Rubber Dampers for the Suppression of Torsional Vibrations in Engine Systems. R. W. Zdanowich and J. E. Moyal. Advance copy of paper before Institution of Mechanical Engineers, Feb.,* 1944 (Y.13.c.R.).

G.e.F.19.—*Rubber Die Technique. Geo. B. Burnside. Reprint from Transactions of the Institution of Rubber Industry, Vol. XX., No. 3. W. Heffer & Sons, Cambridge,* 1944 (PG.7.a.6).

Q.d.59.—*Towards Ideal Transport in Town Planning and Reconstruction. C. R. Bizeray. Light Railway Transport League,* 1944 (PQ.1.b.17).

Q.d.60.—*Victorian Institute of Engineers* (1883-1943). *Diamond Jubilee Souvenir. Victorian Inst. of Engineers, Melbourne, Australia,* 1943 (PQ.1.b.18).

Q.d.61.—*Mechanical Plant for Earth Moving. W. Eric Pyke. Victorian Inst. of Engineers,* 1943 (PQ.b.19).

UC.8.—*Australian Council for Aeronautics Reports*:

ACA-6: The Practical Significance of Notched-Bar Impact Tests. A. R. Edwards.

ACA-7: Fans—Design for High Efficiency. G. N. Patterson.

*UU.c.—*National Advisory Committee for Aeronautics (U.S.A.) Technical Memoranda*:

No. 1068: Heat Transfer in a Turbulent Liquid or Gas Stream. H. Latzko. (From Z.A.M.M., August, 1921.)

No. 1075: The Wall Interference of a Wind Tunnel of Elliptic Cross-Section.

I. Tani and M. Sanuki. (From J. of Society of Mech. Engineers of Japan, Vol. 26, No. 190, Feb., 1933.)

J. LAURENCE PRITCHARD,
Secretary.

NOTES ON POWER OPERATED CONTROLS *for* LARGE AIRCRAFT

by
A. Gouge, B.Sc., F.R.Ae.S.

A. Gouge, Vice-Chairman of Saunders-Roe Ltd., is world-famous as a designer of, and an authority on, Flying-boats. For over twenty years with Short Brothers, of which he became the Chief Designer and General Manager, he was responsible for the design of the Singapores, the Empire Flying-boats, the Sunderland, and many others. He was given the Musick Trophy Award in 1929 for his work. Mr. Gouge is the immediate Past-President of the Society.

A STUDY of the air routes of the world brings out almost at once the fact that some of the most difficult routes are also the most attractive. For instance, the North Atlantic route which couples North America with Europe is certainly one of the most difficult in the world, but also by the fact that it couples two of the most densely populated, as well as the most wealthy groups of people in the world, one of the most attractive. Very long ranges are required and in order that an adequate pay load can be carried and the necessary standard of comfort maintained, it would seem essential to consider much larger aircraft than those operating at the present time.

It is not intended to discuss here the case for large aircraft when longer ranges and larger loads are considered, but rather to assume that such large aircraft will be necessary, be they aeroplanes or flying boats.

Assuming, then, that such is the case and that large aircraft (exactly how large we do not know) will be required, there are many interesting problems which will arise in their design and construction. In this note it is intended to discuss at short length one of these problems, that is, the problem of control operation.

There have been one or two applications of servo control, but in general up to the present time we have been able to operate control surfaces either direct or by means of control tabs and so give the pilot the feel of direct control without excessive loads on the control column or rudder bar. This has involved, in some cases, the application of a close aerodynamic balance of the control surfaces, with the consequence that very small variations in shape during manufacture have produced controls having very different characteristics on aircraft of the same type. These variations have been partially corrected after flight tests by deforming fixed tabs.

There is no doubt that the large aircraft

we have in view could be controlled by somewhat similar methods, but I believe the time has come when we should, as it were, take the pruning knife and cut back some of the excrescences. There is no doubt that large aircraft will force us to think in terms of power operated or power assisted controls.

A general survey of modern control surfaces, even on small aircraft leads me to think that we are giving away a lot in both weight and cleanliness in order that the pilot should control the aircraft direct.

We (and I have been as bad as anybody) have added aerodynamic balance, trimming tabs, control tabs or spring tabs and mass balance. In addition, it is often necessary to fit some device to correct for variations in manufacture. These devices, almost without exception, have made a less efficient control surface, or, in other words, more area of control surface has been necessary to produce the moment required, and this generally means more weight and air resistance.

It is very interesting to review, and would be more interesting to tabulate, the various methods employed to mass balance control surfaces and to calculate what would be gained in weight and resistance if we could design so that mass balance was not required. Very great stress (and rightly so) is being applied to eliminate the last pound of structure weight and some estimations of the cost to an operating company of one unnecessary pound of weight have been published. It is more important to eliminate any unnecessary resistance. It is impossible to mass balance without increasing the weight of the control surface and nearly as difficult to avoid increasing the aerodynamic resistance, so in general we lose both ways, and so do operating companies.

However we arrange to operate the controls some form of trimming device will be necessary in order that the aircraft can be trimmed for any particular condition of flight. The application of an irreversible control unit adjacent to the control surface would eliminate the necessity for trimming tabs and also, what is more important, mass balance.

Irreversible control units could, of course, be fitted without incorporating either power operated or power assisted controls, but no general application has been made. The introduction of power operated or power assisted controls would seem to be a good time to introduce irreversible units and so eliminate in general the need for mass balance. From what has been said previously it would seem that a very good case indeed can be made for the application of power to control operation on all types of aircraft, though I was at the start considering only large aircraft.

In addition to the points I have already made as to the desirability of beginning to think in terms of power operated controls there are one or two other defects in controls operated directly by the pilot, particularly in very large aircraft. For instance, we have to design control columns and rudder bars to take loads of some hundreds of pounds and transmit these loads from the cockpit to control surfaces which may be quite a hundred feet away.

The whole of the system must pass stringent elastic tests which involve not only the system itself, but also the structure which supports it. Another point which can become important is the effect of temperature variation. Mostly we have steel control runs fitted in aluminium alloy aircraft, and in some cases differential expansion and contraction can produce undesirable consequences. In aircraft of the future it will be necessary to instal pressure cabins in many cases in order that the aircraft may fly as high as required to avoid undesirable atmospheric conditions and also to increase the cruising speed. Therefore we now have the additional complication of controlling the aircraft from a pressure cabin.

Automatic pilots are in general designed to operate heavy loads over considerable distances. It could become quite a small and light piece of apparatus once we have the

courage to face the installation of full power operation.

The application of power operated controls can be approached from two directions: (a) the power can be used to multiply the pilot's effort, (b) the power can be used entirely, which would leave the pilot with no load or an artificial one graded to suit requirements.

In (a) the pilot could control the aircraft if the power supply failed by sufficient physical effort, but it has the disadvantage that the complete control run would still be necessary and probably some form of aerodynamic balance. This method is obviously the one to use in the first instance. Thus we have aircraft at the moment where it would be advantageous to cut the aerodynamic balance by a certain amount and give the pilot an assister. This method is applied to several American aircraft and a recent British aircraft in connection with engine controls and the indications are that they will be successful. In this British application the effort required by the pilot to open or close four sets of throttles is divided by six, the force being 24 lbs. without assistance, and four pounds when the assister is connected. In the same aircraft an application of the same principle is now arranged to be fitted to the rudder control for experimental purposes. In the cases referred to the pilot assister or servo is an all electric device developed by a well-known company in this country, and from a series of tests made on the bench there is every possibility of them being successful.

Consider now case (b), where the whole of the control loads are taken by some mechanical device, the control surfaces following the movement of a control indicator operated by the pilot. Once it is decided that such a device is practical, then we can begin to think of eliminating aerodynamic balance and control tabs.

Also by suitable applications we should be able to dispense with trimming tabs and mass balance. If electrical devices are used, then we can eliminate ordinary control runs, using electrical cables instead. Temperature variations will not in general be a source of trouble and the installation of controls in and through pressure cabins becomes comparatively easy.

The advantages to be gained by complete power operation coupled with irreversibility appear to be so great that serious efforts should be made to develop the various types of control units required. The effects of a complete change from manual control to irreversible power control would be that in addition to eliminating the undesirable elements which have already been mentioned we would introduce other characteristics which must be considered in connection with the safety, stability and " feel " of the aircraft. The question of safety is perhaps the most serious, the usual methods of operating the controls have in themselves been most reliable, though such devices as trimming tabs, control tabs, etc., have in some cases been sources of trouble and must always be considered as potential sources. The complete failure of power in a power operated control would be most serious, but there should be no difficulty in duplicating the power supply and in addition to have a storage of energy sufficient to enable the aircraft to be force landed in the event of a total power failure.

A total power failure would in any case mean a forced landing, so there would be no need to store more energy than that required for several minutes' flight.

The failure of an operating unit could be catered for by installing one unit on each control surface and operating them in unison. Such an arrangement would allow for the failure of any one unit (with the possible exception of the rudder), leaving the pilot with one aileron, elevator or rudder as the case may be.

By such means it should be possible to make a power operated control equally as reliable as a manually operated one when all things are taken into account. With irreversible controls we should lose our old friend (?) stick free stability and should

therefore have one less worry. In some cases, of course, stick free stability has been a blessing, but I cannot help thinking that it has only been developed to overcome an inherent defect in the aircraft concerned.

The problems connected with control and wing flutter are becoming of so much importance and are so difficult to handle theoretically that it is almost essential we eliminate any unnecessary potential source of trouble. Irreversibility of controls will in effect make the control surfaces a rigid part of the wing, tail plane or fin and thus make the problem of vibration so much more simple. The same remark also applies to the elimination of control or trimming tabs.

As stated at the beginning of this note, I have been led to think seriously of power operated controls when considering very large aircraft where some device is becoming essential. It would, however, seem that the application of power controls, coupled with irreversibility to any type or size of aircraft would be beneficial, after the initial defects have been overcome.

In conclusion, I hope this short note will stimulate thought and lead to more intense research than we have given in the past to a subject which is becoming very important.

CIVIL AVIATION DISCUSSION

A DISCUSSION on civil aviation, arranged by the Royal Aeronautical Society, was held in the lecture hall of the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, Westminster, London, S.W.1, on Saturday, November 4th, 1944.

In the Chair: Lord BRABAZON OF TARA, M.C., F.R.Ae.S., Past-President.

The CHAIRMAN: This conference was called to discuss certain aspects of aviation. Each aspect would be taken in turn and introduced by an authority on the subject, to stimulate the discussion.

The first speaker was Brigadier-General A. C. Critchley (Director General, British Overseas Airways Corporation).

TRAINING OF PERSONNEL

Brigadier-General A. C. CRITCHLEY, C.M.G., C.B.E., D.S.O. (Director General, B.O.A.C.): The problem of recruitment had to be considered in three phases. The first concerned the present, the second concerned the immediate post-war period, and the third covered the conditions which would obtain when they had reverted to normal procedure.

To-day the B.O.A.C. was flying twice as many miles as it did in 1938, but the increase of its personnel had been very small. As a result, it was stretched very thin throughout its routes, and many more recruits were required in every department. The four main departments were those of the pilots and aircrews, the mechanics and ground crews, the traffic and administrative personnel, and lastly the station managing personnel.

Most of the pilots and aircrews came from the R.A.F. It would be appreciated that three aircrews were required for every machine, it being reckoned that an aircraft should normally operate for a minimum of 3,000 hours per annum, and aircrews could usefully do only 1,000 hours flying per annum, if they were not to be overstrained.

A matter which had surprised him very considerably was that quite a long time was required to train a military pilot for civil air work. One of the original Cadets, a man of outstanding character whom the B.O.A.C. had watched since 1939 and who had completed 2,000 hours flying in Coastal Command, in which the work was of a type somewhat similar to that of the B.O.A.C., was interviewed after having spent a year in one of its training schools, learning to become proficient in civil practice. General Critchley said he had commented that that period seemed to be excessive. But the pilot did not agree, and had said that one could have no idea of the difference between the two types of work. He had added that not one hour of the year he had spent in conversion training had been wasted. That had been proved in several other cases. In America it used to be considered that five years of training was required before a pilot was capable of taking over in the left-hand seat.

Mechanics and ground crews would be recruited from the R.A.F. in the immediate post-war years, as would also the traffic and administrative personnel.

The station managers constituted a very important section of the personnel for civil airlines. They were rather apart from the ordinary run of personnel, because they were asked to do so many things in addition to their airline duties. They must represent British civil aviation in their particular areas, they must meet kings, ambassadors, gover-

nors and business men. They must know how to entertain and how to be entertained, in communities such as those of Khartoum, Karachi, Lagos, Baghdad, Teheran, and so on.

Station managers must be all things to all people.

Eventually the time-expired pilots of the B.O.A.C. would be trained for the work, for they were first class in every way; and if there were not enough of them the B.O.A.C. would probably invite senior officers from the Services, who had their pensions and would be prepared to give a few more years to that type of work.

If the B.O.A.C. could secure recruits from the sources mentioned to meet immediate requirements, it could carry on for some years. During those years it must plan further recruitment in all branches, and General Critchley proposed that that should be done through its training school, with two exceptions, namely, the pilots and aircrews, who would come from the post-war R.A.F., and the engineers, who must take their apprenticeship and training through the proper engineering schools or aircraft manufacturing companies.

The recruitment for post-war aircrews would depend very largely on how far the Government wished civil aviation to be a second line or a reserve for the R.A.F. In his view the Government would be wise to carry on the short-service Commission which was inaugurated before the war and which gave the pilots and all aircrews five years in the R.A.F. Then, he suggested, the best should be given a further five years on reserve, which would be in the civil aviation companies.

That could easily be worked out and would give the airline companies an excellent reserve of aircrew to draw on.

The engineers and ground crews were in a different category, and they should go through the recognised engineering schools before going to civil aviation. There would not be a sufficient number to warrant the provision of *ab initio* training for that class of personnel; even if the B.O.A.C. did that, he did not think it could give them a sufficiently wide training.

The traffic and administrative personnel should come from the British educational establishments, but not before they were 17 or 18 years old. From experience of the lads who had joined the R.A.F. it was found that those who had left school at the age of 15 years had very little idea of looking after anybody but themselves, and one of the greatest difficulties was the problem of trying to teach them, not only to look after themselves, but to look after other people. That was why he advocated that they should not go to the B.O.A.C. before they were 17 or 18 years old.

From the British educational establishments they would go to the B.O.A.C. training school. The length of the course there had yet to be determined. The training was of the utmost importance, and could not be carried out except by the creation of a first-class civil aviation school. In that respect he was on rather more solid ground, inasmuch as some 400,000 lads had been trained in this war and the last through General Critchley's commands and those responsible had had the experience of a great cross-section of people to be trained. The whole tone and spirit of British civil aviation would be determined by the training school; it would be the heart of such efficiency as it was hoped to generate.

It was the intention that every person wishing to serve in the B.O.A.C. should pass through the school, whether he be training to be a steward, a station manager or a pilot. By that means there would be standardisation right through. General Critchley hoped that the B.O.A.C. would be allowed to take over one of the larger R.A.F. establishments when the war was nearer its close. At that establishment it would teach flying, aerodrome control, how to look after passengers, how to look after messes, and everything else.

One of the most important matters in con-

nection with training for the air was that a pupil should be both medically and mentally fit. It was necessary that there should be very much closer medical examination than was being given to-day. Having been passed medically fit, the pupil should be made physically and mentally fit—and there was quite a difference between the medical and physical types of fitness.

The Chief of the C.A.A. Medical Division, speaking recently at the University of Illinois College of Medicine, had referred to a careful study which had been made of pilot failure causes of aircraft accidents, and the comparison with mechanical failure causes. He had said that in a study of some 300 reports of commercial aviation accidents it was shown that in 26½ per cent. of cases the pilot's medical record had indicated some physical impairment. A random selection of medical records had shown that, of all aircrews certified, 20 per cent. had some physical defect. A further analysis had shown that pilot error was the causative feature assigned in 85 per cent. of the accidents investigated.

That compared very closely with the result of an investigation made some ten years ago by the American airlines. It was most exhaustive and interesting, and was published in the "Fortune" magazine. The conclusion, after investigating practically every accident which had occurred during the previous five or six years, was that 95 per cent. of the accidents were caused by pilot error. That did not mean altogether errors in flying, but included other things; for instance, one man had had the wireless loose and it had fallen off. The pilots had just not taken that final degree of care which was necessary.

There were one or two cases of accidents which would not have occurred if there had been a proper medical check-up.

Another very important feature was that of discipline. Nine times out of ten pilot failure or pilot error had arisen through direct disobedience of orders. Civil aviation was a civil undertaking, and as such it was difficult to establish the necessary discipline, as compared with a military undertaking; discipline had to be based on goodwill on both sides. Yet he could think of no other industry in which discipline was so absolutely essential; the safety of the passengers and the success or failure of the airline depended on that main factor.

Defining discipline as "self-control reduced to a habit," General Critchley said it was one of the things which the training school must try to engender in everybody passing through it. It was proposed that everybody should be taught their job at that school, whether it be a cook learning how to prepare meals for passengers, stewards learning how to serve meals, or a traffic man being taught that the customer was never wrong. Pilots would be brought up-to-date in their flying, new gadgets would be explained and brought into use, instruction would be given on the proper drill for aircrews and the hundred-and-one other things which went to make up the civil aviation service. The main theme of the school would be "service," for without it there could be no airline.

In that connection he recalled that Field Marshal Wavell, in his lectures on "Generals and Generalship," had pointed out that the first essential for a General was to be able to look after his men, that it was of no use being an expert in strategy and tactics if he had not the administrative ability to look after his men. Thus the point which General Critchley wanted to emphasise throughout the B.O.A.C. was that "service means leadership." If that fact were driven home, British civil aviation would lead the world, as it well could do.

The training centre of the B.O.A.C. should be a real factor in putting the final polish on all ranks of the British civil airways; and it would keep them up-to-date, not only in respect of new developments, but up-to-date as regards themselves, in matters of turn-out, smartness and all-round efficiency. They had the best civil airline pilots and aircrews in the world to-day, and he was

determined, by means of the recruitment and training plan, to bring the ground organisation up to their standard, in order that, as one happy working team, they could lead the world in aviation, as Great Britain had always done in respect of the things that mattered.

Sir FREDERICK HANDLEY-PAGE (Fellow, Messrs. Handley-Page, Ltd.): There was an immense amount of interest being taken in training and education, which was a very good thing for this country. Sir Roy Fedden had been very active in that respect, with his College of Aeronautical Engineering. It was very pleasing that the B.O.A.C. were tackling the training of their pilots and other personnel in a very thorough manner.

It was particularly interesting to note that, in the training scheme which the B.O.A.C. was to put into operation, everybody would be trained at the same place. That was essential if there were to be unity of thought and real team-work; and any organisation was bound to fail unless all its personnel worked together as a team.

Though every one of the personnel must go to the same school, the time would come when there must be a differentiation in the training of the various pupils. So far as the public were concerned, they accepted the engineering standards of an airline as something which had got to be reached, otherwise the airline could not operate. They must have safety in the air, good pilots, good engineering personnel, good maintenance, and so forth. That was all in the background, like the works of a ship, something accepted as the means by which one could travel in safety from one place to another, giving them confidence that the ship would not suddenly develop holes in the bottom and sink, that the engines would not suddenly reverse and send the ship backwards, that the captain and pilot would steer a straight course.

All the little comforts that one experienced on a British ship were to be brought into the air, and the training of the staff for that work was of a character quite different from the engineering side. It was something which very often was not appreciated here. Again, one appreciated the problems which General Critchley and his staff had to solve when he had referred to the diplomatic connections that one had to make abroad. Behind it all there was something very vital, and one hoped that in their training the B.O.A.C. would give their pupils the right attitude of mind towards the job they were to undertake, rather than to try to cram them with knowledge. If the attitude of mind were right, so that the mind was receptive, the results would be good. If, on the other hand, the B.O.A.C. tried to cram them with information, the training scheme would be likely to produce people of a professorial character.

Group Captain G. . W. WILLIAMSON (Fellow): The necessity for some form of conversion course for men coming from the Service to the B.O.A.C. was even greater in the case of engineers than in the case of pilots. No man, having been a mechanic or something more senior in the R.A.F., could become immediately a competent maintenance man in a great airline. The standards to be attained were those set by the Air Registration Board examinations. The preparation necessary to pass those examinations and to produce the kind of maintenance man required by an airline might occupy many months, if not a whole year. Therefore, not only the B.O.A.C., but all other airlines, should make plans for the training of the men who came to them from the R.A.F., who would have to superimpose on their simple maintenance experience a knowledge of the rather different type of maintenance required in airline work.

Emphasising the importance of discipline, Group Captain Williamson recalled the experience of endeavouring to inculcate discipline into civilians. The Air Transport Auxiliary was manned in the first place by civilians dressed in ordinary clothes, and the

standard of discipline amongst the engineers was extraordinarily low. After extended discussions with the Board of Trade, however, as to the cost of uniforms and the number of coupons to be given up, the engineers were provided with uniforms, and a very great improvement, not only in discipline, but in the standard of maintenance, became noticeable at once.

Presumably not even the B.O.A.C. would rely for its engineers on men who came to it from the R.A.F. immediately after the war, and certainly not from a reduced R.A.F. later on. Some time ago reference had been made to the possibilities of boys running away to the air, instead of, as in earlier days, running away to sea. Young people of both sexes in the future would probably wish to make a career on the engineering side of civil aviation. The Air Transport Auxiliary had tried out hundreds of girls, many of whom had made extremely good engineers on light aircraft. They had reached the stage at which they could be entrusted to remove an aircraft, admittedly a small one, from its case, erect it and test it, and girl pilots were found to fly the aircraft.

Very great help was given in the selection of both men and women by the National Institute of Industrial Psychology and by psychological experts of the R.A.F. at West Drayton. Both those institutions had a form of examination which determined quickly, first, the standard of intelligence of the recruits, who were joining in hundreds, and secondly, whether or not they had aptitude for the kind of engineering work, particularly inspection, to which they were to be applied. By training, by examination and by intelligence tests the very highest standard of maintenance must be secured for airline work.

With regard to the very high proportion of accidents due to pilot error, those who had been concerned with maintenance and flying would know the extent to which pilot error was determined by some small thing that was wrong in an aircraft. That small thing might be, at any rate in war time, a dirty cockpit; dirt might be ground into the floor and get into the bearings of the gyro, so that navigation would go wrong. The wireless set might be loose or some other instrument might cause unnecessary rattle. While the aircraft was in the air, all those small things contributed to the embarrassment of the pilot and took his attention from flying. They must ensure that the very highest standard applied to anything with which the pilot had to deal. It was the aim of all maintenance engineers to attain the very greatest safety in flying.

Sir Alan Cobham (Hon. Fellow, Flight Refuelling, Ltd.): He welcomed the fact that General Critchley attached so much importance to the selection and training of station managers, who would have to conduct diplomatic negotiations on matters which might arise at the air stations on the routes of the B.O.A.C. Having flown over those various routes in the early days, Sir Alan appreciated that the problem was a very real one. He urged that all large British concerns should select most carefully their representatives in the various parts of the world. That applied not only to large commercial concerns, but also to the Services.

Much of the blame for the conditions which existed must rest with those at home. A young man was sent abroad on a mission, but was given no instructions or terms of reference; in consequence, when he arrived at his destination, he put his foot in it.

Mr. Theodore Instone: General Critchley had put his finger on the spot when he had referred to the intensive training which *must* be given, not only to ex-R.A.F. pilots, ground staff and others, but to the whole of the staff that were to run the civil airlines. The reference to British airline "companies" had given him great heart!

Having been interested in aviation for many years, and being a pioneer, like Sir Frederick Handley-Page, he urged that every

governor or ambassador should have on his staff a civil air attaché. The latter should be a man who really understood his business, who understood human nature and was himself human, not a " dug-out " who wanted a job.

With regard to the proposed college, he hoped to see many such technical and training institutions in this country. That reference led him to refer to the Air Training Corps. Having had the privilege of being Chairman of the City of London Squadron, he wondered whether the work and training of the A.T.C. had been fully appreciated. That work and training had been of great assistance when the boys had joined the R.A.F., and the Government had stated its policy of carrying on the A.T.C. after the war.

Finally, Mr. Instone urged that the British aircraft manufacturers should be given the greatest possible encouragement *now*, and that that encouragement should not be delayed until it was too late. He hoped that not only the B.O.A.C., but other airline companies which he presumed would be allowed to operate, would be able to make arrangements now to give orders for the finest machines in the world, i.e., the British.

Mr. ERIC L. GANDAR DOWER (Allied Airways (Gandar Dower) Ltd.): He had operated an airline in this country for ten and a half years. The problem of training engineering personnel was important. In his view it was necessary to establish a College.

Having had the privilege of being elected to the original Council of the Air Registration Board, he doubted whether, at that time, it was appreciated how important the future work of the Board would become. It was responsible for the licensing of aircraft engineers and for the standard and safety of an industry which could be called the " British Air Marine."

This " British Air Marine " must be comparable to their vast shipping industry.

His airline company had accepted boys at 15 years 10 months and placed them under indenture for training as licensed aircraft engineers. Some eight to ten of such apprentices had qualified at 21 and, he hoped, would be a credit to the industry.

While, however, a company could do this for boys unable to afford attachment to an Aeronautical College, youths, who could, should have the advantage of a College.

The standard of the future licensed aircraft engineer demanded it.

Air Chief Marshal LONGMORE: He thought that General Critchley had rather overstated the length of time required to convert ex-R.A.F. personnel to civil flying. For instance, surely it would not take so long as had been suggested for the flight engineer of the Lancaster to become the flight engineer of the York. He was not sure as to the personnel of the aircrew which flew the Prime Minister about, but he had a shrewd suspicion that the flight engineer of the York, in which the Prime Minister travelled, was an R.A.F. man, and was passed as aircrew for taking important personages around and looking after the engines of the aircraft in which they travelled.

One had to be careful to differentiate, of course, between the different types of pilots in the R.A.F. There was the fighter pilot, flying a single-engined machine, who was accustomed to high speeds and manœuvrability of aircraft. He was not necessarily a great navigator, and he relied very much on his radio for finding his way about. Then there were the aircrews of the long-range Liberator and Sunderland, serving with Coastal Command, and in certain cases with Bomber Command. Surely no one could say that those men required training for a year or more in order to fit them for civil flying. They knew their jobs from A to Z, and they were accustomed to travel without many of the aids that were provided in civil aircraft.

For thirty years, said Air Marshal Long-

more, he had been connected with the flying business and had travelled a good many miles, both in civil and Service aircraft, and he could hardly believe that there was so much black magic in the difference between the two types. One could quite appreciate that a good deal of careful training was necessary for some of the personnel of an airline, such as station managers, or stewards; but he felt that they would do the R.A.F. a slight injustice if they accepted that Bomber Command and Coastal Command aircrews were not capable of being converted to civil flying in a much shorter time than General Critchley had mentioned.

It was noted that the B.O.A.C. had a big training programme, which no doubt would be increased in the years to come. But he was not clear as to what hold the B.O.A.C. would have on the personnel when they were so trained, whether there was some financial arrangement whereby the personnel paid for their training and, therefore, were free afterwards to go to other airlines. He would very much appreciate some information on that matter.

General CRITCHLEY: In replying to the discussion, he said he hoped the B.O.A.C. would be able to obtain some advice as to who should look after the finishing school which had been suggested in connection with the training of station managers and other representatives.

The suggestion that each governor and ambassador abroad should have on his staff an air attaché was very valuable, and he hoped it would be adopted by the Government.

With regard to the A.T.C., perhaps the only reason he had not mentioned it was that he was a little self-conscious, for he had had a good deal to do with it, and everyone who had come to the R.A.F. from the A.T.C. had come into his training groups first. There was no question that the A.T.C. had done a tremendous job of work; it had saved the R.A.F. a great number of hours of training in the secondary stage, which was most important, bearing in mind the speed at which training had to be carried out. A well-trained A.T.C. lad saved more than a month in training in the R.A.F., which was an extraordinary achievement. There was no praise too high for the A.T.C. and those who had run it and, naturally, its personnel would have every possible help, so far as he was concerned, when they came into civil aviation.

When the B.O.A.C. was asked to encourage British aircraft manufacturers he had felt that that was not really its business; but it did the best it could by flying their machines as efficiently as possible.

The length of time required to train ex-R.A.F. personnel for civil aviation work had astonished him, and he had asked the men what the differences were. They had told him that, in the first place, civil airline machines flew in much worse weather than did the R.A.F.; secondly, they had to consider the passengers; thirdly, they had to land civil machines with full loads, whereas military machines landed empty. Further, the centre of gravity and hundreds of other factors had to be considered, whereas they had not thought about those things before. Nobody would be more pleased than himself, said General Critchley, if the training period could be reduced; but he could only speak from experience. The men of whom he was speaking had flown for 2,000 hours in Coastal Command. So much for pilots. But the flight engineer in the war-time Lancaster no doubt was quite fit to walk into the same job in civil aviation.

Dealing with the question as to whether the training school would be controlled entirely by the B.O.A.C., or how it should be organised, he said it was difficult to answer. If the B.O.A.C., as the chosen instrument, were the only line flying out of this country, then he was certain that the school would be under its control. He was rather astonished that Mr. Instone had taken

heart from the reference made to other airlines. After all, Mr. Instone and his pioneer colleagues had very soon got into a huddle after they had been operating for a year or so, in order to operate only one line out of the country. It was rather surprising that, after that experience, he should want two or three airlines flying out of the country.

Great Britain was the only country in the world which had flown two airlines over its borders in the pre-war years. He did not know much about them, but they seemed to have cut each other to ribbons by their competition. America had only one line, the Pan-American Airways. He did not wish to be looking over his shoulder all the time, competing with his own friends and countrymen, when there was enough business in the world to keep them all busy. However, there were a great many divergent views on that subject!

With regard to the life of the pilots, he said the pilots had not been so well looked after as they should have been. The B.O.A.C. had agreed with the pilots that they should enter a pension scheme to start with, so that at the age of 45 they would get a high rate of pension and could be retired; and probably at that age they should be retired. He had suggested to them, and they had agreed, that, having joined the organisation at the age of 20, they should go anywhere and everywhere they were asked to go during the first 15 years, to fly in any country and be based at any station. But on reaching the age of 35 they would be asked where they wanted to settle down—in Africa, India, England or elsewhere—and the B.O.A.C. would try to meet their wishes, so that they could bring up their children and lead a more or less settled home life.

During the next ten years, between the ages of 35 and 45, it was proposed to give them three months training each year on administrative work, as station managers or line superintendents or something of that kind, so that they could do the work for which they were best suited. He personally would hate to see the great knowledge and great loyalty of those pilots lost to the B.O.A.C. The plan, of which he had given the general outline, had been discussed with the pilots, and it appeared to have been accepted.

In conclusion, he said there were no finer pilots or aircrews in this world than those in civil airlines to-day, and he hoped to be able to look after them administratively in the manner in which they deserved to be looked after.

THE ECONOMICS OF AIR TRANSPORT

The CHAIRMAN: The next speaker would be Major R. H. Thornton, M.C. (of Messrs. Alfred Holt & Company), who would introduce the subject of the economics of air transport.

Major Thornton was interested in a very old-fashioned form of transport, namely, shipping! At the same time, he was an air pilot of long standing and piloted his own machine. He was a member of the Air Registration Board, and also a very valuable member of the Committee over which Lord Brabazon presided.

Major R. H. THORNTON, M.C.: Having had no commercial connection with aircraft himself, he could only indulge in a little free thinking and break the subject into headings for discussion.

Subsidies.

To what extent were they necessary, how should they be controlled, and how best could they be applied?

They had reached a point at which it was of no use merely asking whether subsidies were necessary. There were fields for self-supporting air transport and there were fields for air transport which were not self-supporting, but which would be extremely valuable to the community and should be opened up as such. It was ridiculous to say they were necessary as a generalisation. If that claim were made, he must ask with

what object and for whose benefit were they necessary? In his view it was not true.

Assuming there were subsidies in certain cases, how were they to be controlled? That was difficult, because once they fell from grace there was a tendency not to bother so much about making two ends meet; one was likely to feel there was no reason why a subsidy should ever stop; there was no automatic stop to prevent further sliding, and the slide went on for ever. The greatest menace in regard to subsidies was the difficulty of deciding how and when to stop them. On the matter of control of subsidies he was completely and absolutely beaten.

But the subject could be approached from another angle, by considering the best methods of application of subsidies. If there were no truth in the suggestion that there should be universal subsidisation of all forms of air transport, then he considered that the subsidy should be applied, broadly speaking, route by route. That eased the difficulty of determining where to stop, for the subsidies could at least be canalised; there would be routes for which no subsidy was necessary, and they could cling to the principle that these must be made to pay.

If a subsidy were applied to any route, then ideally it should be proffered by all the States interested, whether politically or economically, in that route. It might be agreed, for example, that the Atlantic crossing needed a subsidy. (Incidentally, one could see estimates of the cost of a passage across the Atlantic at any figure from £10 to £140, and if one asked one of the men responsible if the figure given were really the cost, he would say: " No, but that is what I thought we ought to charge.") However, if it were concluded that the route required a subsidy, then ideally it should be granted to a group of approved operators of the different nationalities primarily interested in the development of that route. It might be said that a Belgian or a Swiss who travelled on that route was reaping an advantage for which his country was not paying. But that would not matter; the countries primarily interested in international intercourse and trade, who were subsidising that route, would say it was satisfactory to them.

If that principle were tolerable, then the subsidy should be given in a form readily assessible, leaving all operators still on a common competitive level. A good deal of such subsidising was done already. In some countries one paid 2s. 6d. for landing on an airport, for which one should pay several pounds; or one might receive services free of cost altogether. But all operators on a subsidised route should be on a common competitive level. If there were a route sufficiently obstinate to call for a fuel subsidy, it was quite possible to contemplate the sale of fuels at international subsidised prices.

Air Mail.

The burning question in connection with air mail at one time was that of the surcharges versus the " all-up " principle. Other problems were whether mail should be carried in combined passenger and mail aircraft or in specialised mail carriers; whether mail contracts should be separated from subsidies; and what should be the proper approach in order to arrive at appropriate rates for the carriage of mail, a matter which was quite important and separate from that of postal policy to the consumer.

Airports.

There was an alarming increase in specification of airports. Who was to pay? There was a real risk of frustrating air transport development, due to siting problems. Were the machines to be built for the airports, or the airports for the machines? In shipping there had been an admitted compromise. There were cases in which ports had been built for ships; but in 99 cases out of 100 the ships must be built for the ports.

Ground Formalities.

The delay that could be caused by attempting to apply intricate and leisurely methods of documentation, customs, etc., to the new

air age, with a few reluctant concessions thrown in, was incalculable. The subject required an entirely new approach. Airports used by international services should have extra-territorial status, such that no transit formalities whatever were imposed by the States over which the service operated.

All-Weather Punctuality.

This was one of the biggest problems in connection with the commercial development of the aeroplane as a public vehicle for business men. The Continental business man before the war had had substantially to adopt a fixed procedure. He always travelled by air between the months of May and October, but he never arranged to travel by air between October and May. Obviously, unless there were improvement, aeroplanes would be used for only half their time. Therefore, the institution of something approaching all-weather punctuality was of immense economic consequence to the commercial development of the aeroplane.

Short-Haul Possibilities.

There seemed far too much inclination to think of aeroplane travel in terms of greater and greater range. As the United States domestic air transport had developed, the average length of passenger journey in miles had steadily diminished. The reason appeared to reside in direct competition with railroad passenger expresses. These were answered by the aeroplane making trips over distances as short as 150-200 miles, not by much saving in time on the individual trip, but by a far more frequent service of expresses than any railroad system was normally capable of providing.

Just as the Londoner wanted a train every minute between Marble Arch and the Bank and every ten minutes between the City and the suburbs, so he wanted trains between London and Birmingham or Liverpool more frequently than the railway companies could provide. A curve could be drawn by a sufficiently imaginative person showing that for a distance of 150-250 miles there was required a frequency of half or three-quarters of an hour. They could not get that on the railways. In his view for short hauls the aeroplane had an extremely valuable and lucrative future.

Air Freight.

America seemed to have gone wildly optimistic about air freight, and there were whole magazines devoted entirely to the marvellous advantages of the aeroplane for the ordinary common or garden merchandise. If ever there was moonshine, that was moonshine. The aeroplane had little or nothing to steal from the surface carriers of the world in respect of ordinary merchandise, but it would create an entirely new traffic of its own. Obviously it should take the form of a daily delivery over wider areas than had been possible hitherto, dealing with all sorts of articles which were required daily and were required to be fresh, whether Cornish cream, newspapers, news reels, or fresh fish. For example, one could carry fresh turbot from Hull to Zurich, and come back with Swiss trout. The distance was only about 400 miles, and the aeroplane should be able to carry it that distance for about 3d. per lb. That was a perfectly good example of air freight; it was not stealing anything from anybody, but was creating a new service.

With the aid of the aeroplane a European "mail order" business should be quite simple and possible for makers of a wide range of products, from cosmetics to split pins. A manufacturer would probably find it worthwhile to double the size of his business, with the aid of a catalogue and advertisements, delivering his products on the doorsteps of his customers in the course of the morning following the receipt of their orders. That would pay for itself, not because air freight was cheap, but because the increased cost of carriage would be compensated for by economies due to the larger output.

Mr. CAMPBELL ORDE (B.O.A.C.): The equipment in civil air transport must be used in the most intelligent way; the problem was different from that of war-time operations, and that was why a considerable period of training was necessary to enable those trained initially for war-time work to adapt themselves. The equipment was becoming much more complicated, and it was essential that the crews should understand the best way to use it. An airline could not afford to make it too automatic; the aircraft had to operate through a tremendous range of conditions, unfortunately still in relatively unprepared circumstances. The aircraft operators looked to the aircraft industry to help, by means of better equipment, better instrumentation, better means of control of the use of the engines and their consumption of fuel, to keep the costs down to the absolute minimum. And it was necessary to have the right men in the cockpit and on the ground.

Some rather depressing remarks were made by Major Thornton concerning airports, and one wondered whether he had painted rather too black a picture. The airports available before the war were dealing with comparatively short stage services.

If Liverpool wanted an intercontinental type of service it would have to make an airport suitable for that, as opposed to the shorter class of operation for which the airport had been used before the war and for which it was adequate. Since then, aeroplanes had been produced which could fly the longest stages that would be required, the worst case being something like 3,500 actual miles.

When he had talked to aircraft designers in this country and abroad, as he had done this year, they were all quite satisfied that they could give the operators what they wanted for the very long range flights within quite a modest take-off run. They had said also that if the airports were larger they could not really give much more in performance for it. The indications were that somewhere within 10,000 ft. would look after any sort of air operations with the present kind of aeroplane; and he was inclined to agree with that view.

Dr. ROXBEE COX (Fellow, Chairman Power Jets (Research and Development) Ltd.): It seemed to him that, as Major Thornton had alleged, the economics of air transport could not yet have been studied very seriously, and in so far as there were economic theories, he felt that a great many of them were incorrect. The point made by Major Thornton, that where subsidies were granted they should be such that all benefited equally, was very sound. In thinking of airline economics, however, they should think rather of making an airline as economical as possible than of making it economic. There were so many reasons for an airline other than sheer commercial reasons, and it might well be that the economic advantage which an airline would give would not appear tomorrow or the day after, but perhaps five or ten years hence. In other words, an airline would perhaps open up a part of the world which would become a commercial proposition only after it had been opened up.

Another point brought out by Major Thornton, and one that was too often forgotten, was that an airline would bring into existence a new form of traffic. It gave proof of its ability to provide something which no other form of transport could provide, namely, high speed. One felt that in the studies that were made of the economics of airline operation there was too great an insistence on ton miles per gallon, which was too easy and facile a criterion on which to work. He did not think that anyone would be able to produce any reliable simple criterion of that kind, because there were so many special circumstances attending each particular case. But they should be thinking more of ton miles per hour, or in some other way bring into the economic study of the problem the fact that the aeroplane was pro-

viding speed to a degree which no other form of transport could provide.

There had been some tendency in certain quarters to suggest that it was necessarily economical to fly relatively slowly, but he could not believe that that was true. It might well be that, with the evolution of the sort of equipment now available, there was a very low limit to the economical speed of operation. But they were coming to an era when high speed would be widely achieved and, in his belief, relatively cheaply. He had in mind the development of the gas turbine, which he believed would prove to be a revolutionary factor in aircraft economics. There was a tendency at the moment, with reciprocating engines and airscrews, to stabilise at economic speeds in the region of 220-230 m.p.h.; but with the gas turbine he believed the economic speed of aircraft would be somewhere between 300 and 400 m.p.h., and for relatively short hauls even higher speeds would prove quite economic and extremely convenient.

They should attempt in some way to assess the economic value of speed, and should give very close attention to the scientific exploration of aircraft operation and economics.

Mr. PETER MASEFIELD (Associate Fellow): Major Thornton had put up a thick smoke screen of doubt and uncertainty, and the suspicion that aircraft operation could never be economic. With that the speaker disagreed profoundly. Instead of talking of air transport, they should talk of *commercial* air transport. One or two striking advances had been made recently which would accelerate development. Since 1919 the costs had steadily decreased while speeds had increased. Those two factors together afforded a most healthy sign, and he believed the reduction of costs and the increase of speed would proceed at an accelerated pace. There was nothing magic about air transport cost figures; in the United States the figures were kept in great detail, under about 160 headings, so that one could ascertain the exact costs of operation each quarter. From an analysis of the figures one could see the general trend of the air transport business.

It seemed that there were five heads which should be considered when discussing airline economics. One was the speed and height at which the machines should fly, and the speed depended very much on the height. At ranges such as that across the North Atlantic it had been said that in order to achieve 80 per cent. regularity of operation it was necessary to fly at 25,000 ft. That would affect the economics—not necessarily adversely.

The second factor was the economic range. At one time it was about 10 miles, but it had gone right up because, with the advent of variable pitch airscrews, and so forth, the landing weight on some aircraft was very much less than the take-off weight. Thus after a machine had got into the air with a full load it was necessary to burn a large proportion of the fuel carried before the total weight was reduced to the figure at which it was permitted to land. That affected the cost of operation because it limited pay loads on the shorter ranges.

Thirdly, there was the problem of load factor. The railways had a tremendous advantage, in that they could operate at load factors of 150 or even 200 per cent. In airline operation the position was completely different. One might suppose that theoretically a load factor of 100 per cent. would be most efficient for airline operation. That was not true, because if the load factor were 100 per cent. and if there were the normal fluctuation of traffic, on many days there would be a demand for 150 per cent. American airlines operating under war conditions at 80 to 90 per cent. load factor were not in an ideal position. At 65 to 70 per cent. load factor they could do away with the priority system and the need for booking a long way ahead, which cost money and discouraged passengers.

Fourthly, the utilisation factor was important. General Critchley had mentioned

3,000 hours operation per annum for each machine as the aim. The Americans were operating for a greater number of hours, but were doing so by running at uneconomic times, starting at 2 o'clock in the morning and finishing at 2 o'clock next morning. Operation for 3,000 hours per machine per annum was probably as high as anyone wanted to go, because the curve of reduction of operation costs flattened out as the operation period increased above the 3,000 hours' level. If operating intensity were increased from about 2,000 to 3,000 hours there was a decrease of about 10 per cent. in specific operating costs. If the intensity were then increased to 4,000 hours per annum, there would be a decrease of costs to the extent of about 1 per cent., so that it was hardly worth doing; great sacrifices had to be made to achieve the extra 1,000 hours per annum.

Finally, there was the question of first cost, which mattered much less than was often supposed. It was calculated that a 10 per cent. increase in first cost would make only 1 per cent. difference by way of increase of operating costs per hour. The reason was that it was spread over the whole period of operation throughout the year.

Summing up, he said it seemed that they could now get near to a cost of about 4d. per revenue passenger mile, a figure which should tend to decrease.

Sir Roy Fedden (President, Royal Aeronautical Society): Three or four months previously the Council of the Royal Aeronautical Society had met to discuss why civil aviation was in its present state, and what could be done about it? The Society was very anxious and determined to play its part and to make civil aviation more vital. It seemed that one of the first things to be done was to emphasise the importance of civil aviation. There could be no question about the vast capacity and future for civil aviation, but it was necessary to put it over to the ordinary man in the street. So far, he submitted, that had not been done. The man in the street was really proud of the pilots, of the R.A.F., and of their machines, but did not realise what civil aviation would mean to the whole world, what great things it could do, if properly organised, towards preventing wars and bringing people throughout the world closer together.

He felt that the Society could do great things on those lines. Just as the public in the Victorian era were greatly interested in the mercantile marine and the Navy, so they must let the public know the nature of the problem with regard to civil aviation to-day.

Recalling General Critchley's references to education and his splendid ideas about training, and his own work for the Minister of Aircraft Production in connection with the proposed College of Aeronautics, the President urged that all branches of the industry must have better education; there must be more specialisation, and the vital questions of leadership and discipline had to be considered. When visiting works and air stations in different parts of the country he had been particularly impressed by the fact that there was such excellent material in the lower ranks, the young tradesmen, the mechanics in the works, and the men in the lower grades of the R.A.F. Those men could be better educated and their outlook broadened. The great trouble was that they had not people possessing qualities of real leadership in the highest grades.

Expressing the view that in civil aviation before the war maintenance was nothing like what it should have been, he said there were great openings in that direction. Even during the war, he believed, if it had not been for the Royal Air Force in one of the outlying areas they would have had some really serious holds-up and troubles in connection with their own operation of civil airlines.

With regard to looking after passengers he had travelled on both American and British lines, and appreciated that there was a lot to be learned from both. He urged that we should get the best from both sides.

As to the technical side, he said that safety must come before anything else, and speed came next. But they must develop their innate engineering qualities to the full. To make things a little different and a little better than anybody else must be their aim. He thought this country would go forward modestly with a small series of types, and make them better and more suited to its own requirements than by going into the realms of too big machines and too many types before they were ready.

Captain LAURENCE PRITCHARD (Secretary, Royal Aeronautical Society): He protested against the practice of comparing the costs of aviation with the costs of railway, steamship and other forms of surface transport, and said he looked forward to the day when 90 per cent. of transport would be by air. After all those who had developed the railways had not continually made comparisons with the stage coach. Just as the stage coach had disappeared, so he believed that in the future many of the types of surface transport now used would disappear and their place would be filled by aerial transport. No doubt it would be said that they could not afford it, but the same had been said about other things when they were introduced, and yet they had developed, as gramophones, wireless sets, cinemas and motor cars. They were now afforded by many of a class which could not have afforded them when they were first introduced.

In the future he thought they would have air freight from Australia to England, Australia to America, and so on, just as goods are carried by train from London to Manchester to-day.

Major THORNTON: Replying to the discussion, he emphasised that he was not suggesting that air transport would always need to be subsidised. He had merely assumed, for the purposes of discussion, that it needed subsidies in certain respects or certain areas, and had then considered which would be the healthiest method by which to apply it and how to prevent it getting out of hand.

With regard to airports, he should have made it clear that runways might not be more than about 10,000 ft. But, looking at it from the point of view of the municipal planner, if one added to the length of runway the amount of sterilised air, it would come to about 6,000 yards for a very modest trans-Continental airport. For there had to be provided 500 yards at each end as graded ground, so that a pilot could come in a little early or a little late without tipping up on his nose. Then, for a 1 degree climb, there must be a length of 850 yards before one could erect anything to a height of 50 ft.

Discussing air freight and the criterion of ton miles per hour, he preferred the criterion of ton miles per annum. If speed were increased, one was doing more revenue-earning work to set against annual costs.

The cost of air carriage could never be brought down to that of the slower forms of carriage. But there was an enormous premium in the gift of speed, and it would work its way into the economic fabric of the community.

The rate of development of the aeroplane depended far more on the rate of change of human habits than on the rate of technical development in engineering. In his view, the reason the Americans had developed commercial air transport to the extent they had was that the American public had been prepared to tumble into an aeroplane whenever and wherever it was offered as a public vehicle; and it was this backing and the vast continent they were operating which had enabled them to go ahead with the energy that they had applied to it. The European mentality, including the English, had not yet responded to anything like the same extent to the opportunities afforded by the new vehicle, and it was that which was lagging, rather than technical development.

The cost figures put forward by Dr. Warner should be taken with a large number of grains of salt; they needed careful appli-

cation. One of the most interesting points to note was that about 40 per cent. of these intensive domestic American airline costs were actually unaffected by the fact that the aeroplane was the vehicle used. They would still apply if one used a perambulator.

The CHAIRMAN: The next two speakers were Mr. Hives, whose work at the Rolls-Royce Company had received world-wide recognition, and Mr. Roy Chadwick, the chief designer at Avro's, equally famous for his design of the Lancaster and other machines. Mr. Hives would deal with Engines for Air Transport, and Mr. Chadwick with Civil Aviation Aircraft.

ENGINES FOR TRANSPORT AIRCRAFT

Mr. E. W. HIVES, C.H. (Fellow): It is very interesting to note that in all the discussions and publicity which has recently been given to Civil Aviation, no doubt has been raised as regards the reliability of the engines as they exist to-day.

Plans are being made for longer journeys at higher speeds and at greater altitudes which would have created grave concern as regards safety and reliability a comparatively short time ago.

It should therefore be acknowledged that the engine designer and manufacturer has achieved a high degree of success. This does not, however, leave any room for complacency, as there is still a lot more to be done, but the progress already made definitely indicates that the engine manufacturers have laid sound foundations upon which to build.

There is now a vast accumulation of data and experience on the technique of design, manufacture and operation of aero power plants, and the engine manufacturers are in a position to meet any reasonable demand in the way of power, fuel consumption, weight, reliability and compact installation.

Careful consideration must be given by the users when deciding upon the power plant specification to ensure that the best compromise is attained in all-round economic operation. This can only be arrived at in conjunction with the engine designer and from the detailed analysis of airline experience as shown by a breakdown of the cost figures, on which there is a great deal of information available.

It is usual to measure the life of a civil transport engine in hours' duration instead of miles flown.

Comparing the engine overhaul periods with other forms of transport, the average railway locomotive is expected to cover approximately 100,000 miles between overhauls, and the best road transport may reach a similar figure. A number of the engines used in civil transport to-day cover approximately 150,000 miles between overhauls, and there is every reason to believe that this figure can be improved upon.

The customer expects his fares to be based on mileage, with a premium for an express or high-speed service. It is suggested, therefore, it is wrong that any credit should be given for the length of time the engine is in the air, and therefore the hours between overhauls should be based on mileage rather than time. It is submitted that mileage is the logical basis for aircraft and general maintenance periods, and not hours.

The chief commodity the airlines have to sell is speed; the comfort can only be a relative figure compared with other aircraft. They could scarcely hope to achieve the comfort of the liner, or supply the meals equal to a restaurant.

There are no *mysteries* about aero engines. Everything that is done, and all the things that happen, can all eventually be justified or explained in terms of perfectly normal mechanical engineering.

They had been told that no engine is any good for this civil job unless the price is quoted in dollars; or again, that no engine can fit the civil requirements unless it is specially designed as a civil type; or that the only engine capable of survival in the competitive world is the large capacity

engine, running at low piston speeds and low boosts.

He subscribed to none of these views, as the recent adaptation of British liquid-cooled engines to civil use has shown.

The adaptation of a successful military type to civil use is a matter of readjustment of the relative importance on certain detail characteristics, and it is here that they looked for the help and co-operation of the operators.

The power plant specifications so far advanced cover a wide range of features.

The aircraft designer wants double the normal cruising power for take-off, and sufficient reserve of power in each engine above normal cruising power to retain safety of operation with one engine out of action. Under these conditions there must be no change in specific fuel consumption. He also requires minimum drag of the power plants.

The pilot wants a minimum number of manual controls and full automatic control of components to maintain the desired operational conditions during each flight.

The maintenance engineer calls for plug changes and filter inspection at 100-hour intervals, and nothing more until complete overhaul at 1,000 hours. He also wants to change power plants in the minimum time, and specifies that the overhaul of each engine must not exceed 500 man-hours with minimum replacement of parts.

The traffic manager wants the weight and fuel consumption to be an absolute minimum, whilst the commercial manager wants his engines cheap to buy.

Put into a more concise form, the requirements of the civil transport engines are:—

Highest possible maximum continuous cruising powers at altitudes ranging from 10,000 to 25,000 ft., with the take-off power approximately twice that of normal cruising.

Single lever engine control with power plant components automatically controlled to maintain best conditions, leaving the pilot to fly solely on the indicated airspeed reading.

Low weight.

Low installed drag.

Low fuel and oil consumption.

Reliability over long periods with minimum maintenance.

Long periods between overhauls.

Low cost of overhauls.

Compact design and quick changing of complete power plants.

Low initial cost.

The improvement of these features has always formed the basis of the engine development programme; most of them have been incorporated in military engines.

The difference between the military and the civil version is a difference in the "mix" of these characteristics.

Consider by illustration the introduction of a new material. It may be applied to increase power and so reduce specific weight, or to extend the overhaul life at the same power, or to allow increased operating temperatures and so to reduce cooling drag. The military and civil users would both acclaim the technical advance, but would probably utilise it in different directions.

The manufacturer is obviously out to give the customer or the operator just what he asks for, but on the other hand the manufacturer is anxious to see that his line of development is not misdirected by demands which cannot be justified.

Overhaul Life and General Reliability

For example, in the matter of overhaul life, one frequently heard that 1,000 hours between overhauls is an absolute necessity. Now the life between overhauls is obviously connected with the running conditions within the engine, and it would be reasonable to expect that the life of a big engine at low specific power would surpass that of a smaller engine running at higher boosts and higher piston speeds, other things being equal.

If, however, the installed weight of the larger engine was 3,740 lb. and it gave a

1,000-hour overhaul life, and the smaller engine was 3,300 lb. installed and gave a 750-hour life, what would the comparison be then? In a year the one would be overhauled three times against the latter's four times, with a difference in expenditure of, say, £350. But the earning power of the difference in weight between 3,740 lb. and 3,300 lb., expressed as pay load, would probably exceed the £350 spent on the additional overhaul. The figures quoted are quite possible ones and only go to show how dangerous it can be to demand longer and longer overhaul periods *without considering the cost in other directions*. Particularly is this so now that really quick-change power units are an accomplished fact.

There is another point about overhaul periods which merits discussion, and that is in the nature of a definition. What is the overhaul period? They had recently been looking at the life statistics of some of the alleged " long-livers " amongst engines, and they found that whereas the overhaul life is quoted at a quite high figure in hours, in some cases only 75 per cent. or less of the engines ever reach the stated time expiry period, the other 25 per cent. having been removed at odd times as unsatisfactory for one reason or another.

Now they realised what it means to an operator to have to change an engine, by force of circumstances, at some time other than that originally budgeted. The service is delayed, inspection schedules are out of step, and if the engine has to be changed away from an established base, the expenses, direct and indirect, can rapidly mount to an alarming figure.

They appreciated, however, that with shortage of supplies, and all the other many difficulties of war-time operation, unusual courses are adopted; but they looked forward to the time when the term " overhaul life " really means that time to which 100 per cent. of the engines will run without failure. Power plants which are easy to change and cheap to overhaul should remove the incentive to chance just that few extra hours of life.

When the manufacturer states his recommended overhaul period, it should be a firm and confident figure and not just some arbitrary point in the falling away of a mortality curve. With quick-change units they would rather see 100 per cent. of the power plants run to 600 hours than 90 per cent. of them run to 800 hours, leaving the other 10 per cent. " fallen by the wayside." They were certain the operators would concur with them in this view.

Let them, therefore, separate their reliability target into two parts. The first objective should be 100 per cent. reliability up to some conservative number of hours between overhauls. The second and subsequent objective should be a gradual and cautious extension of the overhaul period up to as long a period as economic research would indicate as desirable.

Now that they are allowed to spend a little time on the problems of development of transport engines, this meeting might be interested to know how the manufacturers intend to deal with them. It is obviously logical to start out with an engine, embodying all those developments which are known and proved from the experience of war-time requirements. Such an engine built into a power plant will be run for long periods on a hangar with a flight airscrew, and the whole unit will be subjected to conditions simulating typical civil operations. Sandstorms and tropical rain can be laid on with no undue complexity of test equipment. When these tests have shown the unit to be generally reliable and maintenance free, a representative aircraft should be fitted up and taken on world-wide operational trials.

They were all pleased to know that B.O.A.C. have formed a Development Flight to undertake this kind of work, and welcome this practical form of co-operation. Co-operative development of this sort will ensure that British engines meet every requirement.

They must be sure that the power plants are impervious to convectional rain, either in flight or when on the ground; that they are proof against the ingress of grit and sand, and that they can be operated and maintained under climatic conditions from the equator to the poles.

They felt very strongly that the engine manufacturers must be prepared to accept the design and development responsibility for all the installation features which go to make up the complete power plant.

This will ensure maximum reliability of all components on which the successful operation of the power plant as a whole depends.

It also has the very important advantage of introducing standardisation of the power plant for any particular engine which may be installed in different types of machines, and facilitates the provision for quick power plant change.

Power Plant Changes

The era of complete power plant change is with them. A power plant complete can be changed in an hour. Quicker changes than this can be accomplished if the customer specifies it, but the majority of the reduction in time from an hour will be by way of expensive and complicated ground equipment to facilitate the change. They could not help thinking that it is to be preferred to concentrate on giving the power plant complete with its engine 100 per cent. reliability up to the time when its scheduled removal arrives, when the actual time of removal is not so important, than to anticipate ultra-rapid power plant changes when an aircraft is on the service and the snag arises. Eventually they will have complete operating records showing them exactly how many delays could have been avoided by an ultra-rapid power plant change, and upon this information they would be able to make a balanced judgment of the relative merits.

Fuel Economy

He felt that the most important single feature for development in engines for civil use is that of fuel economy. The experience of British operators gives the items of cost associated with engines and spares in the following approximate percentages of the total operating costs:—

Obsolescence	3%
Insurance	1½%
Maintenance and repairs (labour, material and on-cost) ..	12%
Fuel and oil	18%

There is a general similarity in these figures with those given in respect of American and Canadian airlines. Because there is no standardisation in the methods of presentation of figures by accountants, it is often difficult to get a reliable read-across. The percentage outlay on fuel and oil is, however, quite interesting; whereas the British figure is given at 18 per cent., Dr. Warner gives 12 per cent. for general American airline practice, and recent published figures for Canadian operation give it as 13 to 14 per cent. The difference between the American and Canadian figures on the one hand, and the British figures on the other, are completely accounted for by the lower fuel prices brought about by the American proximity to the sources of supply and also the relatively higher labour costs in American and Canadian operations, coupled with the fact that there is more labour involved in a dollar's worth of air transportation than in a dollar's worth of fuel and oil.

Whether they took the American, Canadian or British figures, they were left in no doubt as to the importance of fuel economy, for every improvement in this direction not only knocks something off the figure of 18 per cent., but—and this is even more important on long flights—it allows the fuel saved to be replaced by revenue-earning pay load.

There are different ways in which fuel economy may be achieved, and here again they pleaded for the balanced judgment.

It is frequently claimed that the best specific fuel consumption is given by the big engine running at low piston speeds and at cruising boost which makes it virtually normally aspirated. This statement, however, requires qualification, because in their experience, from examination of data obtained on a range of engines from 21 litres to 42 litres shows that for a given horsepower at a given altitude the specific fuel consumption remains constant.

Better fuel consumptions are obtainable by raising the cylinder compression ratio, but for a given engine this leads to a reduction in the permissible cruising and take-off power due to detonation; it can therefore be argued that advantage of a higher compression ratio can be utilised by making a larger engine which will restore the original powers at the lower specific consumptions. The larger engine, however, is accompanied by an increase in the installed weight, and weight of structure necessary to support it, together with higher form drag.

As an illustration of this he quoted a practical example of an engine of over 40 litres capacity compared with a lower compression engine of under 30 litres capacity.

Cruising at an altitude of 10,000 ft. the large engine shows a specific consumption of .415 lb./b.h.p./hr., while the smaller engine shows a specific consumption of .44 lb./b.h.p./hr., the difference being accounted for by the compression ratio.

The installed weight (with airscrew) is of the order of 3,740 lb. for the large capacity engine compared with 3,300 lb. for the smaller engine, which means that only on flights of over 28 hours does the fuel saving of the bigger engine justify its heavier weight when expressed as pay load.

If, however, the cruising altitude is increased to, say, 25,000 ft., where the required cruising power is higher, the difference between the consumption becomes less on account of the larger engine with its higher compression ratio having to run richer to avoid detonation. A further consideration is operation on less than the full complement of engines when it becomes necessary to increase the cruising power of the remaining engines. Under these conditions the high compression engine is at a disadvantage.

These points only serve to show that the selection of the engine calls for a very balanced judgment of the factors involved, as the simple difference of specific fuel consumption is by no means the outstanding factor.

They felt from consideration of cases such as these that a more fruitful field is to endeavour to maintain consistently low fuel economy by accurate control of fuel/air ratio, even distribution between cylinder, judicious selection of compression ratio, and full utilisation of the energy in the exhaust.

The fuel log figures charged from many North Atlantic crossings show a very wide variation on all engines. Nor did they find themselves in agreement with the ultimate necessity for a flight engineer as a method of ensuring consistency of low fuel consumption. Automatic regulation of all components, including the best fuel metering, power characteristics and airscrew speeds are accomplished facts. They thought that a flight engineer will ultimately be as unnecessary in an aircraft as in a motor car.

The man, his personal equipment, and the extra equipment built into the aircraft on his account, cannot possibly represent less than a loss of 500 lb. of pay load, and when the engine manufacturer designs away the necessity for this loss, he should be credited with this increase in the aircraft's earning power.

However, as engine manufacturers they did not carry the full burden of responsibility in question of fuel economy. By a continuous struggle it will be possible to reduce fuel consumption by the odd few per cent., and no efforts will be spared on their part to achieve this; but let them not

lose sight of the fact that there are other very remunerative sources of saving outside the influence of the engine.

It is quite a normal and accepted practice to carry anything up to 25 per cent. extra fuel to allow for errors in navigation, errors in weather forecasts and technical inabilities to make let-downs and landings through conditions of ice, clouds, or bad ground visibility. As this can represent anything from 30 to 50 per cent. of the pay load on such a route as the North Atlantic, surely here is a most fruitful source of increase in pay load.

Improvement in aids to navigation and weather forecasts can save more fuel than the engine manufacturer can ever hope to do, and at the same time give that regularity of service which is missing in present-day operation.

The purpose of this talk has been chiefly to indicate that the designer and manufacturer of transport aero engines is fully alive to his responsibility. He appreciates that the first axiom for air travel is that the propellers must keep turning.

He strongly recommended that operators should go to the engine man with both his hopes and disappointments. They should treat with great respect recommendations and suggestions put forward by the engine man.

He pleaded for the greatest possible breadth of vision, so that they did not find themselves with a product unnecessarily overdeveloped in certain characteristics, and lacking in some other equally important direction.

The earning power of aircraft engines cannot be assessed separately from the airline as a whole, and they felt confident that if the complete picture is always kept in mind, the result, so far as they were concerned, will be an engine well able to hold its own in the world of £ s. d., or even dollars!

CIVIL AVIATION AIRCRAFT

Mr. ROY CHADWICK said if one took as a basis a passenger air liner suitable for world use, there were several arrangements possible, such as the tailless, the tail-first, the tandem and the orthodox. The tailless did not give enough space except in huge sizes. The tandem offered a certain amount of saving in structure weight in large sizes. But, on the whole, he thought the four-engined orthodox type was the most practical at present and for some time to come.

As for size, except for very long range there was no need for the very large machine, and a better system was to have smaller aircraft working at higher frequency. There was pay load advantage in shorter stages. As an example, if the range was 4,000 miles and the pay load 7 per cent., then at 3,000 miles it rose to 12, at 2,000 miles to 18, and at 1,000 miles to 25 per cent. of the gross weight. He suggested 1,000-mile stages; speed over ground 250 m.p.h.; cruising speed 300 m.p.h.; maximum speed 400 m.p.h. Then one could fly from 8 to 12, 12.30 to 4.30 and 5 to 9, which was as much as anyone wanted, except those in a very great hurry, and could cover 3,000 miles in a day.

Air transport features Mr. Chadwick placed in the following order of importance: safety, regularity, comfort, operating cost, cruising speed, original cost. He made the observation that first cost was less important than many thought. In one year's flying, for instance, the cost of the fuel might well be the same as the first cost of the aircraft.

One important aspect was that of control. Should one carry a large crew to do all the work, or a small crew and rely on radar? He personally wanted a competent crew, with good communications.

The CHAIRMAN: The name of Mr. Hives was not nearly so well-known in this country and throughout the world as it should be, having regard to all that he had done for

British aviation. Probably no one had contributed more than he to the success of British arms.

He noted that no reference had been made in it to jet propulsion, and he hoped sincerely that the meeting would not allow the discussion to pass without a strong attack being developed for the jet against the reciprocating engine.

Again, he would like someone to press for a definition of "horse-power." Mr. Hives was one of the worst offenders in that respect. He had started with an engine of 1,000 h.p., and over the week-end it had developed about 2,000 h.p. Then they were told it could be run on civil aircraft at 60 per cent. power; so that finally it was running at a power which was greater than that for which the engine was designed. That made it extremely difficult to arrive at the actual cruising power in which the engine could indulge.

Mr. Chadwick had short-circuited a number of problems by stating that he would talk only of modern aircraft, or standard aircraft. But one wanted to hear whether he was going to run into troubles with landing gears on machines of 250,000 lbs.

Another matter was that of landing in conditions of complete invisibility. The ability to do that would be essential, at any rate on the North Atlantic service, where landing grounds were as fog-bound as that at Newfoundland from time to time.

On the question of pressurisation, he said the first country that developed it really satisfactorily would have a very great advantage over others, for they really could not ask passengers who were over a certain age to fly for 10 hours at 23,000 ft. The technique must be developed.

Mr. W. E. PETTER (Fellow, Chief Engineer, Aircraft, English Electric Co. Ltd.): With reference to Mr. Chadwick's comment on the importance of fuel cost in the operation of present-day aircraft, he said the facts that the operator could pay the equivalent of the cost of the whole aeroplane in one year in the cost of the fuel used, and that 18 per cent. of the total running costs represented the cost of the fuel used, rendered it imperative that the closest attention must be devoted to the problem. It would be both an engine and an aeroplane problem. They required engines which used a cheaper fuel, and less of it per h.p. hour. Perhaps Mr. Hives could indicate what they might hope for in those two directions.

Quite apart from what was expected from the engine makers, however, the aircraft manufacturers must do something about it. The drag of the present-day aeroplane was such that it required much too much power to propel it through the air, and he could see every possibility of arriving at a minimum drag co-efficient not very much more than half of that which obtained to-day—though they would suffer many headaches in achieving that. The effect of that on cost of fuel, and the practicability of flying long range and carrying a reasonable pay load, would be terrific.

A large amount of the drag unnecessarily built into their present-day aeroplanes was that associated with the power plant. Perhaps that was at least as much the responsibility of the airframe maker as of the engine maker. The latter naturally sought to protect himself by insisting upon a power plant which he knew would work, although in terms of drag it would be very often anathema to the airframe maker. The two would have to get together and must do somewhat better in connection with the installation of the power. Further, he hoped the engines would soon be removed altogether from the wings of the aeroplane; he was sure they must not stay there much longer.

Asking for more information with regard to long and short hauls, Mr. Petter wondered how many aeroplanes would be of the type described by Mr. Chadwick, flying 1,000 miles at 300 m.p.h., and how many would be flying perhaps 200 mile or 300 mile hops, presumably at a cruising speed of 180 m.p.h., or something of that sort. Would the ratio

be 2/1 or 10/1 in favour of the small one, because if it were to be something of the latter order surely they were not giving it quite enough attention, either on the airframe or the engine side?

The problem of pressurisation needed more consideration. Mr. Chadwick would agree that the machine he had mentioned, cruising at 300 m.p.h. for 1,000 miles, would require to be pressurised. Mr. Petter was quite sure the problem could be solved without any very serious increase of structure weight or cost of the aeroplane.

Finally, recalling the statement made earlier by Mr. Masefield, that a 10 per cent. increase in the first cost of an aeroplane would increase the operating costs by only 1 per cent., he commented that surely that was an invitation to improve their engineering, for even if the makers of aeroplanes had to charge a little more for their product, it would soon be appreciated that they were delivering the economic goods!

Air Commodore R. BANKS (Fellow, Director Engine Development, M.A.P.): He was inclined to agree with Mr. Chadwick that if the trip from this country to Australia were made in 1,000 mile hops it would be all to the good, because air travel was the most boring in the world. For those who wished to get to Australia quickly he suggested a service of super mail planes with room for passengers, and driven by turbines, so that they would travel at 500 m.p.h.

On the engine side, his view was that they should develop a civil engine as they did the military engine, with high take-off power; that permitted cruising at a lower percentage of the maximum. In other words, instead of having a mediocre engine with mediocre take-off power, he would prefer good take-off power and a cruising power of 35-40 per cent.

Emphasising the importance of freedom from fire risk, he urged that the way to achieve that was to devote minute attention to detail.

Expressing himself as being absolutely full out for the turbo, Air Commodore Banks voiced the opinion that ten years hence they would not use the reciprocating engine for big horse-powers. The gas turbine would be used as a pure "jet" where high speeds and high altitudes were concerned; but the turbine-driven propeller would be employed to a large extent, particularly for the lower altitudes and more moderate speeds.

Mr. OGSTON: As one connected with the fuel business he was surprised and impressed by Mr. Chadwick's statement that the transport aeroplane would use a quantity of fuel, the cost of which per annum would be equivalent to the initial cost of the aeroplane. A brief calculation showed that the statement was roughly true. Assuming a post-war cost of 1s. 6d. per gallon for 100-octane fuel, and a consumption of, say, 200 gallons per hour, the total fuel cost would be £45,000 for 3,000 hours operation.

On the other hand, ships such as the "Queen Mary" also used a phenomenal amount of fuel in the course of a year. He did not know how much such a ship burned, but assuming that the consumption was approximately 0.7 lbs. per b.h.p. hour, and that the power was 200,000 b.h.p., the cost would be nearly £1,000,000 in the course of a year's operation, so that the discrepancy was not so very great as might have been indicated by Mr. Chadwick's statement.

A safety fuel, i.e., one which did not evolve inflammable vapour at normal temperature, would be of advantage in a minor crash or an emergency landing which might result in structural damage to the aircraft, but did not kill the passengers by impact. In the case of an aircraft using petrol, the chances were that an engine would be torn off or a fuel tank damaged, and petrol would leak on to the ground, so that immediately the whole aircraft would become bathed in a sea of inflammable vapour, and if there were a source of ignition in contact with the vapour there would be a conflagration which would prevent the possibility of

the passengers getting out. On the other hand, if a safety fuel, or Diesel oil, were used, it would have to fall on a part which was sufficiently heated to cause it to evolve vapour; the spread of fire, if any, would be very much slower than with petrol, and he submitted that the passengers would have a chance to get away.

However, the matter would have to be tested by experience; crashes would inevitably occur with the jet-propelled aircraft. He understood that, in the crashes which had occurred so far, the pilots would have been killed by impact in any case.

Mr. IVOR LUSTY, Associate Fellow: With reference to the problem of a safety fuel, he found it most disconcerting to take-off in an aircraft with about 2,000 gallons of inflammable fuel around him.

With regard to engines, he said that after a civil aircraft was boarded by the passengers the engines were started, and there was a whirr for a time. Why that should occur in engines in the design of which so much care was devoted he did not know. He submitted that that was one of the matters of detail which would have to be discussed in connection with civil engines.

The use of rubber mountings for civil aircraft was quite a bone of contention, and there was much discussion as to whether or not they were worthwhile. A side issue in that connection was that engines had to be overhauled frequently, due to the engines being out of balance.

Coming to the problem of cruising speeds and cruising powers, he said he had just completed an investigation of it from rather a different angle. On a long range flight it was necessary to carry a considerable excess of fuel, because one did not know what the meteorological conditions would be. But having taken on board the amount of fuel which it was thought prudent to take, was it best to stick to the normal long range cruising and very likely arrive at the end of the journey with a lot of petrol still in the tanks, or to use it up in increased speed, i.e., planning the flight as it progressed, in order to arrive at the destination with just the safety margin that was necessary? Slight savings could be achieved by increasing speed in order to consume the fuel once it was put on board. Insurance costs decreased with reduced flying time, the periods between overhauls were more valuable because one could get more out of them, and the crew's flying pay was reduced.

They should not restrict themselves to low cruising powers. Another incidental factor was that one increased the power with a following wind and not necessarily against the wind.

New demands cannot readily be created in a framework of low and stationary living standards, while they can readily be created when there is a high or rising standard of living.

Roughly speaking, Standard of Living is proportional to Production minus Re-investment, and in this country post-war it would seem inevitable that the first of these two factors will not be as high as could be wished, while the second must necessarily take on a relatively high value in the interests of reconstruction and modernisation. It would therefore follow that Britain's standard of living in the immediate post-war years will certainly not be a high one, however much one might wish things to be otherwise.

New markets and new tastes will be slow in their growth, and to budget on them in any post-war planning would be unduly optimistic. British air transport should direct its attention to those activities which can be truly utilitarian, so that without diversion into the ways of display or the seeking of national kudos, their transport services should be utilised first of all to help raise the standard of living. The new demands and the new markets will then inevitably follow.

The word he wished to emphasise was "follow"; they must tackle first things first.

Mr. C. G. GREY, Founder Member: He welcomed Mr. Chadwick's emphasis of the importance of safety first, for he had been trying to drive into people's heads for about thirty-five years the fact that flying was dangerous. For many years Sir Alan Cobham had preached that flying would not be a commercial proposition so long as it remained an adventure. Furthermore, as Lord Brabazon had said after Dr. Warner had dazzled them in the Wilbur Wright lecture with astronomical figures showing the safety of airline flying in the U.S.A., he found that it was still thirty times more dangerous than travelling by train. That was a matter for all young aircraft designers to look into. Of course, the question was whether anybody really knew anything about aerodynamics at all!

Recently he had seen a rather curious puzzle which some might care to solve. Two aircraft which had been much publicised were the Flying Fortress and the Liberator. One of them appeared, to the ordinary eye, the most highly streamlined thing that was ever built. The other had a nose like a bulldog and it was about as streamlined as a bulldog, including the curly tail! The curious thing was, according to his best-informed friends, that those two aircraft gave almost identical performances with the same engine power. Therefore they must both be wrong, because if either came nearer to being a proper aerodynamic shape than the other, it would obviously have a better performance.

Mr. TRESILLIAN (Associate Fellow): He felt that there still remained an enormous number of things which could be done to reduce fire risk; so many people were working on the problem that it should be almost impossible for an aircraft to be brought down due to fire, if a number of things which they already knew were done. For example, he suggested the possibility of building the wings around the fuel tanks and other combustible materials in steel instead of low melting point light alloys.

Mr. DAVENPORT (Fellow, Technical Director, Westland Aircraft Co.): He urged that more consideration should be given to safety, and went on to emphasise the necessity for solving the problem of pressurisation. Mr. Chadwick would have to allow a larger percentage of the structure weight for the provision of that comfort, and Mr. Hives would have to allow anything from 100 to 150 h.p. from his engines. The safety of the aircraft depended also on the blowers, and he suggested that the blowers should be subjected to a test equal to that given to the engines.

It seemed to him that civil aviation was not going ahead as fast as it should because the majority of people who had not yet flown were afraid. They should be given better chances to fly. Pressure chambers were being built for the full use of those interested in which the largest or nearly the largest mock-up cabin could be tested at the equivalent of any altitude.

Captain FRAZER-NASH (Director, Parnall Aircraft Ltd.): Developing the demand for speed associated with safety, he suggested an alteration in the type of wing, so that the flying speed could be increased to 300 or 400 m.p.h. at reasonable heights, and the addition of some development of the flap and the Handley-Page slot in order to reduce the landing speed to 55 or 60 m.p.h. That might appear to be rather futuristic at the moment, but it meant merely increasing the effective lift surface at times of take-off and landing. There were various patents and provisional patents dealing with the matter, and it was difficult to see why the effective wing area should not be doubled mechanically at the time of landing, rather than that the pilot should have to climb probably thirteen miles into the stratosphere in order to ensure low-resistance travel.

It seemed that they had rather lost interest in the heavier, cheaper and relatively safer fuels. He wondered whether there would be a development in the direction of using a light Diesel engine for aircraft, not so much on the grounds of economy, but in the interests of safety.

Mr. S. SCOTT HALL (Associate Fellow): Seven years ago there was a good deal of talk about safety, and people were carrying out experiments with petrol and Diesel oil. Having been away from aircraft design for seven years, he had hoped that on his return he would have found that aviation had become very much safer; but from the discussion so far it appeared that not much further progress had been made. Possibly that was due to war influences. Recalling Mr. Grey's reference to figures showing that flying was thirty times more dangerous than travel by train, he suggested that it would be of the greatest value to aircraft designers who were thinking about civil flying to have before them a complete analysis of the features in aircraft which contributed to safety.

Mr. CROCOMBE (Fellow, Chief Designer, General Aircraft Ltd.): He suggested that for the very large sizes of aircraft very considerable economies were to be gained by adopting the tailless design. He had in mind machines of from 200,000 to 300,000 lbs. all-up weight.

Major BULMAN (Fellow): In reference to an earlier remark of the Chairman he confirmed that the acceptable cruising power of an engine is in fact a variable quantity, and for a given type may well increase six months hence from to-day's figure, thanks to and depending on the amount of intensive development work applied to the type of engine in the interval, on the bench and in flight. It was a tribute to, and not a reflection on, the engine maker that such cruising powers showed progressive advance. Their enthusiasm and confidence in the gas turbine must not blind them to the fact that it, too, must pass through this essential phase of sheer hard development running, breaking, mending and modification before it achieved in reality the high hopes for it they all shared. There is no magic short cut in sound engineering.

Group-Captain G. W. WILLIAMSON (Fellow): He would like to comment on the fact that the Royal Air Force had given the aircraft designers some assistance through Committees which might not persist in civilian life. One of them was the Technical Equipment Committee. When it was desired to add something, the Committee first considered whether they could do without it or whether that particular item of equipment could be reduced in size or weight, thus allowing more fuel, bombs or pay load to be carried by the aircraft. Another Committee had considered all designs of military aircraft to ensure that maintenance would be kept at the minimum and at its most efficient. In America there was no such Committee, and he had taken over aircraft which had had solid sheets of aluminium at the points where one would have to inspect rudder and elevator controls. That meant making modifications when the machines came to this country; in British aircraft, on the other hand, that type of modification would have been suggested in the first place by the Committee concerned with maintenance problems, so helping the designer before he actually made the part and preventing subsequent modification.

They could never eliminate the flight engineer under present arrangements, even if Mr. Hives could make his engines 100 per cent. automatic; nor could they unless the designer eliminated points which now required attention by the flight engineer in civil aircraft. At any rate, they could never eliminate him in time of war, in view of the multiplicity of vitally important duties. There was a case on record in which the flight engineer had taken control after the

pilot was killed, although he had died himself as the aircraft landed. Under war conditions the flight engineer had to do all sorts of jobs, such as coupling up controls which had been shot away, pumping petrol from tank to tank, and so on, and until they could get away from the practice of installing six tanks in the wings, it would be necessary to carry a flight engineer other than the pilot.

Wing-Commander MACMILLAN: It seemed to him that throughout the years of development, if the designer had desired to get a few more feet of height, a few more miles per hour, out of his aircraft, he had done it at the expense of the air crew. A certificate of airworthiness was issued in respect of the aircraft, but there was nothing to regulate the designer in the direction of limiting the duties he imposed on the human element. Thus it was necessary to carry a qualified engineer who understood the scientific control of power output to operate his particular engines. Anything that could be done to limit the amount of manual control would be a good thing.

The CHAIRMAN: Dr. Roxbee Cox had proposed an aeroplane of 600 tons weight some years ago, and he asked how he felt about it now.

Dr. ROXBEE COX (Fellow, Chairman, Power Jets (Research and Development) Ltd.): The statement referred to was as true to-day as it was at the time he had made it. He could quite fairly plead that at that time he was engaged in solving the academic problem of how big they could make aeroplanes if it became desirable to make them as big as possible; how big they needed to be made was an entirely different matter.

With regard to types of aircraft, he recalled that Mr. Chadwick, having examined the various geometrical forms which he could give to his modern aeroplane, had concluded that the conventional form was the best. Then Mr. Crocombe had thought that the tailless form might be better, but had limited the application of the tailless form to sizes of 200,000 lbs. or above. Dr. Roxbee Cox said he would have thought that the *tailless* aeroplane could have been of almost any size; he had in mind the design of the Westland Hill "Pterodactyl." On the other hand, the *all-wing* type of aeroplane for military purposes was necessarily of some 200,000 lbs. weight; and if in the civil aircraft of that type they were to have all the comforts which had been demanded, it would be of at least 300,000 lb. weight, if one were not to have to stoop to get through the doorways, and so on. His own feeling was that there was a great field possible for the tailless aeroplane of quite reasonable size. Putting the problem in an over-simplified form, if the tail of an aircraft were cut off, there would be less drag than if it were left on. The type, too, was particularly suitable for gas turbine engines.

In suggesting air travel by 1,000-mile hops at an average speed of about 250 m.p.h., Mr. Chadwick had had in mind the comfort and convenience of the passengers, and such travel could be described as very comfortable. But that sort of progress could not be applied universally, for there were still journeys such as the trans-Atlantic and trans-Pacific crossings, so that they must provide for greater range. Perhaps Mr. Chadwick was suggesting that, for the size of aeroplane between 100,000 and 150,000 lbs. weight, 1,000-mile hops would be appropriate, and that the longer ranges would require the use of larger aeroplanes. But even if that were the suggestion, Dr. Roxbee Cox was not convinced that it was true, for very long ranges could be attained with relatively small machines by the use of certain devices.

Coming to the gas turbine and jet propulsion, he said the gas turbine did give the aeroplane the chance to do very much greater speeds than in the past, bringing

about a revolutionary change in air travel. It had been said that the jet propulsion engine was seriously limited in what it could do by its high fuel consumption; that statement had been widespread, but it was wrong. It was a gross over-simplification of the fact that the ordinary simple jet propulsion engine, running at ground level and at low speed, had a high fuel consumption. The real point, however, was that when the jet propulsion engine was properly used it did not fly slowly, nor did it fly at ground level. At the high altitudes at which it would fly, the ordinary jet propulsion engine was an economical device, and aeroplanes fitted with it would travel a very long way at a very high speed. It could give them, in carrying capacity and range, all that the reciprocating engine could give, and it would get there in half the time. From that statement, working backwards, one could find out the fuel consumption of the jet propulsion engine!

Work was being done on the development of the gas turbine, as the result of which it would appear that the engine would be still more economical than at present and would give ranges greater than could be achieved with the reciprocating engine.

It had been said that in respect of real power there could not be very much difference between the use of high grade petrol and ordinary kerosene, and that the kerosene would be cheaper, even if not much cheaper. Furthermore, although both Diesel oil and kerosene were liable to catch fire, they were nevertheless safer than petrol. So that, on the counts of sheer financial economy and of safety, he would say that kerosene was a better fuel to use than petrol, and it should be used in the gas turbine. If something cheaper still were required, there were prospects of being able to burn fuels of still lower grade; in view of distribution costs, probably they would not be much cheaper, but they would be a little cheaper, he imagined, and therefore attractive.

Discussing the point that 25 per cent. extra fuel should be carried on account of contingencies in airline operation, Dr. Roxbee Cox pointed out that the faster the rate of travel, the less the extra amount must be. Extra fuel was necessary to provide against errors in navigation and against head winds, both of which were distance contingencies, and not time contingencies. Thus, inasmuch as distance was being covered more quickly, presumably the provision against the contingency would be reduced in bulk.

Finally, he agreed with Mr. Grey that they knew very little about aerodynamics, and added that, sad to relate, the faster they flew, the more profound their ignorance became. More and more factors of more and more mysterious nature appeared to creep in, and there was not the least doubt that in the future, in achieving very high speed, they would have a most difficult series of aerodynamical problems to overcome.

Mr. CHADWICK: In replying to the discussion, he expressed disappointment that it had not given him more assistance in connection with his next job of work; he had been full of hope that he would have picked up many very valuable points which he could use in connection with the next civil aeroplane, and possibly commercial aeroplane, with which his Company had to deal.

Commenting on the Chairman's reference to landing gear for the 100-ton aeroplane, he said he did not think it would present any trouble at all up to 100 tons; at least it would not present more difficulty than would many other problems which would have to be dealt with in that size of aeroplane. He agreed that blind landing must be developed to absolute perfection. Nothing frightened him more than to land in bad visibility, hoping to reach the aerodrome, and that there was not a chimney or a hill or something else of that sort between the clear sky which he could see and the ground he could not see.

He had taken it so much for granted that pressurisation would be applied that he had

not mentioned it. It was quite obvious that passenger-carrying aeroplanes would be pressurised, and it was just a question of detailed design and development. Both Mr. Petter and Mr. Davenport, who had mentioned the matter, were very well aware of the work that was being done; indeed, they themselves had done a lot of it in order to help to solve the problem of pressurising and humidifying and general air conditioning on commercial aeroplanes.

It was pleasing that Mr. Petter was so optimistic about reducing form drag to about half its present value. He also sympathised with Mr. Petter's remarks about getting the power plant off the wings. That had been thought of for many years and various attempts had been made; but somehow he did not feel that he would like to sit in an aeroplane fuselage when the engines fitted inside it were running. With regard to the question of noise and vibration as distinct from drag, he was told by pilots that in the fast jet-propelled aeroplanes they did not hear the noise of the engines, and the turbines were so smooth running that there was no vibration and, indeed, these jet-propelled aircraft were very pleasant vehicles.

He hoped that he would be able to design a civil aeroplane with a very large fuselage and beds, bunks, armchairs, kitchen, bar and many other things which would fly as fast and have the same pleasant freedom from noise and vibration.

The idea of flying commercial aeroplanes on reasonable stages, in the interests of increasing the pay-load and resting the passengers, was important because it decided very largely many features of design in a civil aeroplane. He hoped the feeling of the meeting on that matter would be shared by people who produced specifications for aircraft and who were going to operate them, because lately a great deal of pressure had been brought to bear on flying non-stop for thousands and thousands of miles. It was very difficult indeed to produce an aeroplane to fly over great distances with anything like a reasonable pay-load. When they had the very economical jet which Dr. Roxbee Cox had mentioned it would probably ease the problem.

On the matter of safety, and particularly fire risk, Mr. Chadwick called attention to the development of the nitrogen system, which he believed would be used universally on civil aircraft as well as on military machines; and they might have to stick to the self-sealing type of tank, though he believed the tendency would be to use integral wing tanks.

Commenting on Mr. Ogston's reference to fuel costs, Mr. Chadwick remarked that he had mentioned cost of fuel only as an excuse for wanting to disregard the initial cost of the aeroplane, in the interests of making more beautiful and better British aircraft! However, the point was interesting.

With regard to Mr. Scott Hall's remark that years ago people were talking of safety in aviation, and that after a lapse of seven years it appeared that nothing further had happened in that direction, he said that very little had happened, so far as he knew; but he wanted to stress that something had got to happen in that direction. Perhaps the war and its problems of increasing performance had diverted their minds from the question of safety; but it must be given attention, and he felt sure that much of the work that Sir Frederick Handley-Page had done in the past on the slotted wing would come back into use, to give them higher lift wings. It was a very difficult mechanical problem, and the aerodynamical side was also difficult on account of the great moments which were produced by high lift devices and which controlled the characteristics of the aeroplane, and probably in connection with the higher lift devices they would have to use a movable tail.

Finally, he agreed with Dr. Roxbee Cox, in respect of the all-wing aeroplane, that nothing less than one of about 300,000 lb. weight was likely to accommodate the passengers. Fuselages were becoming bigger

all the time, and if they were to listen to the gentlemen of the B.O.A.C. they would be still bigger. He did not see how they were to have a reasonable thickness-chord ratio if they were to obtain the same accommodation in an all-wing aeroplane.

Mr. HIVES (Fellow): Replying to the discussion, he said it happened that engines to operate in conjunction with pressure cabins were available for use for transport. It was recognised by all that the real terror of the sky was icing. Much of the inability to keep to schedules was due to the terrifying effect of icing conditions. Now it was argued that pressurised machines were essential. They should not expect fare-paying passengers to accept the hazards that had to be met in icing conditions. A space had been provided which was free from ice, and they had to make use of it. They had provided the engines.

He did not hold out much hope for Mr. Petter with regard to reduced consumption. The aero engine as he knew it was as good as anything they could get in any other field. He believed the only reason why the Diesel engine had not gone ahead for aircraft was that it did not fit into the aircraft requirements very well. They were becoming stabilised on double the power for take-off as for cruising. The Diesel engine would be very much heavier than the present engine if they were to attempt to maintain that same ratio.

The utilisation of exhaust energy was a potential remaining to be explored. It meant additional weight, additional complications and additional maintenance, and one must balance the problem very carefully to ensure a return for it.

For the starting of engines one was allowed only the size of battery required for the small motor car. There had been the struggle to get more out of it, and if one considered the proportional weight of the starter equipment, one would arrive at about the same result in the case of the motor car. It was really the fact that it cut out, and one had to turn the engine over very slowly. On the whole, starting troubles were not very prevalent; the real point was that they could ensure an easier start if they would accept more weight.

With regard to rubber mountings, he did not accept that they should use them as a means for fitting less good propellers, but if their use prevented vibrations and discomfort to the passengers it would be well worth while.

Whilst agreeing that speed was relative to comfort, he urged that the greatest comfort was to get the journey over quickly. They would never be able to sell the idea " Travel by Imperial Airways and enjoy your lunch on the way to Paris." Passengers would prefer to get there quickly and to have a nice lunch on arrival. Although it was said sometimes that one would hate to see competition in speed of aircraft, there would be a lot of competition and they ought to have speed. After all, they really could travel safely at high speed.

The fact that his Company was in on the jet propulsion business could be accepted as evidence that in their view it had a future; otherwise they would not have devoted to it the amount of energy and talent which they had applied. The jet would very likely follow the conventional engine. The auxiliaries and additions on the present-day engine amounted to much more than the whole engine used at the time of the last war, and yet they all paid a dividend. The variable pitch airscrew did a very good job, as did the supercharger and a lot of other auxiliaries. He believed that in the same way the jet would develop and become progressively more efficient.

Finally, on the question of the flight engineer he emphasised that one did not want to carry in the air crew a fellow who was a " tuner upper," a man who would tune the engines. The time was coming, he hoped, when it would be possible to dispense with the temperamental carburettor. Having arrived at that position, they should get

better results by getting rid of manual control.

GROUND ORGANISATION

Mr. W. P. HILDRED, C.B., O.B.E., M.A. (Director-General of Civil Aviation): In opening the final discussion, he said that the previous discussions had a very close bearing on the topic of ground organisation. In the short time at his disposal he would prefer to raise the question of the trend of matters in this connection. He did not propose to talk about the different types of ground facilities because all those present knew about them as well as he did himself, and, much better, the impact of the development of aircraft in relation to the ground organisation which had to serve it. Therefore, he would prefer in a few opening remarks to ask a few questions and then to set down ground organisation, as he saw it, in four categories.

The first thing was the aerodrome, which might in its embryonic form be a small meadow or from which one could go to the multi-runway airport such as the future called for in connection with long haul traffic in this country and America. Between these two extremes there was a vast gulf, and one of the factors of outstanding interest and importance was the enormous difference in basic cost between the primitive airports of earlier days and the extreme development that would be necessary to deal with the future aircraft of high wing loading.

The second thing—he raised these points in their essential sequence in order to raise questions in a moment or two—was the meteorological service. Before a flight was planned it was necessary to take account of all that could be gathered about the weather, and it seemed to him that some sort of international organisation was already inherent in the meteorological service. There were observers at different points making their observations and sending them out at predetermined times and in such a manner that charts could be prepared which would be intelligible to any nationality. This involved the use of teleprinters and other means of communication, and the development of complete co-operation. It seemed to him that meteorology set the pace for internationalisation, and it was to be hoped that the unification that had already been achieved, although not as perfect as it might be, would be followed in other matters which concerned aeroplanes and flight even more closely.

But when they had the aerodrome and the meteorological service they had not finished. There must be the control system to co-ordinate every movement and every activity connected with aircraft, and this control system must include the collection of evidence with regard to accidents and the provision of safety measures. All this information could not be obtained without a whole network of increasingly expensive communications in various forms. All these things were growing everlastingly more expensive with the increased demands which the modern aircraft brought in its train. As he had already said, it was one thing to have a small field as an aerodrome, but it was quite another to have the sort of aerodromes that were being planned for places like Idlewild and the type of aerodromes they had in mind for this country.

Whilst it was agreed that the ground organisation should, as far as possible, be on the ground, further consideration immediately made it clear that this could not altogether be achieved. In order to use an aerodrome an aircraft required an undercarriage, but an undercarriage stole a certain amount of pay-load. According to the type of aircraft, the number of passengers which had to be left out cut seriously into the operator's revenue.

Furthermore, it was not possible to give the captain of an aircraft proper meteorological information and navigational direction without at least giving him a radio set to enable him to cope intelligently with what

was coming to him. In this connection, as a member of the Air Radio Advisory Committee, whose job it was to examine wartime development in radio devices, he had listened with great interest and respect to the increasingly elaborate devices made possible by radar development, etc., and again the point that came to his mind was the amount of pay load likely to be stolen by putting on board an aircraft the sort of devices which modern ingenuity made possible.

Whilst he would not deal with the various devices he would mention, in passing, the sort of trend which occurred to him in listening to what had been said concerning these developments. It might be a long day before they had an aeroplane which obtained its motive power, direction and guidance completely from a radio power station instead of from the power units which had been under discussion earlier in the meeting; but it would be quite possible to have an aeroplane almost completely controlled from the ground even to-day, without any other control in the aircraft than an efficient radio receiving set. The cost, however, would be absolutely prohibitive. He hoped he would be forgiven for mentioning the question of cost, but it was a point which, as experts, they must give their minds to. Whether they liked it or not, it was a fact that after the war the Chancellor of the Exchequer would have many pulls on the public purse, and civil aviation would not be the first or the second or the third of them.

The reason he mentioned this was because it was the conventional practice in most countries for the cost of the ground organisation to be met, generally speaking, by the State. There were, therefore, two points he would like to put for any discussion which might follow. The first was, was it necessary in the interests of safety and regularity to incur any particular item of cost, and secondly—if the answer to the first question was Yes—should that cost be met by the Government or by the municipality—and here he was making a reference to the present position of municipal aerodromes—or should it be met by the operator who stood to lose in his effective pay-load, or should it be passed on to the customer in the form of an increase in his fare?

It might be said, in reply to that, that unless there was uniformity the question could not be answered, that it would be quite hopeless for one operator in one country to charge the cost of these things on to the fare when some other Government, without going into the question of concealed subsidy or otherwise, saw fit to carry the cost themselves and thus allowed the operator to refrain from making an increased charge, and thus setting up a disequilibrium in the rates of charge over any particular route.

He believed that before the war the Continental operators as a whole in Europe had a very unenviable climate compared with South America or North America, yet they managed to achieve 97 per cent. regularity. In other words, they were 3 per cent. short of perfection. In achieving that, he believed he was also right in saying that for every aircraft mile flown—at any rate by the operators on the small scale in this country—there was a present from the State of 1/9, and he therefore raised another question for consideration which lay at the heart of the research that was now going on: was the extra 3 per cent. worth it? He had his own views on that, but he would like someone in the subsequent discussion to speak on that point. Was the extra 3 per cent. worth it?

This led him to a further question which arose when considering the increasing ingenuity of ground facilities, particularly radar. Were the developments now being planned and which might be made obligatory having the right effect on pilots? Were they packing their brains into boxes and sealing them in an endeavour to reach perfection at the expense of the five senses of the pilots who were to be masters of the aircraft in the future? It seemed there would be a much reduced call on the senses and the technical perfection of the pilot and a reduction in

the keenness of his reaction to the changed conditions. Personally, he wondered whether the pilot of the future would have to owe a little too much to the technical perfection of mechanical devices. It would be interesting to hear other views on all these points.

His final observation was how far would it be possible to achieve unification in ground organisation generally. It was quite clear that there was a responsive and clever technical equipment both in the aircraft and in the terminal aerodrome, and it would be folly to put up with unresponsive and primitive equipment at the various stage posts en route. Yet the modern aircraft which had to fly, as Mr. Chadwick had said, thousands and thousands *and* thousands of miles, would have to cross in its journey various countries where there was not the convenience, nor the interest in aviation, which they had, and which could not possibly provide the necessary aerodromes or facilities which they would expect to find, and must find, at the stage posts en route.

Indeed, it might be found that in certain places the equipment would be quite unusable and, indeed, might be worse than not having them at all. It was said that if a pilot got used to a certain type of runway he found difficulties when he had to land under other conditions. He therefore ran risks in landing at places where there were not the devices he had been used to; in fact, there was a bigger risk under such conditions than if there were no facilities at all. This all came back to the point already raised as to the dependence of the pilots on the technical requisites for their trade.

In conclusion, Mr. Hildred said he had tried to cover three or four questions and he would run through them again because he hoped they would bring forward helpful suggestions and expressions of view. What he had tried to cover was on the following lines: Was it agreed as a desirable objective that, broadly speaking, the ground organisation should be on the ground? Should the aircraft be capable, even allowing for the modern perfection of these devices, to navigate itself, or should they pass over to a state of affairs in which the aeroplane was nothing but a bead run along a string, which was a popular custom in other countries? Was ground organisation as they knew it, in its full acceptance, tending to spoil the skill of the modern pilot, and if so, was that a good thing? What radio devices were really wanted in the modern aircraft? He did not know how far this could be taken, but they had learned so much from the various things which modern war had produced that it was an interesting question both in the interests of safety and of flight regulation, and it could not be ignored. They wanted to know how many things would be wanted, how many could be done without and how many were vital.

Was there a formula which would enable harassed Government officials to balance the cost against the value of the device? That question arose in any new development. It took a certain amount of money to maintain it, and was there any formula by which it was possible, thinking these things out from an administrative angle, to balance the cost against the desirability of the particular device?

Was it thought that the public really wanted 100 per cent. regularity, and was the cost of the additional 3 per cent. he had mentioned worth the result? · If the public, in their judgment, wanted these things, who ought to pay for them? Should it be the Government, the municipality, the operator or the client?

Again, how far was it thought possible to achieve an international standard in these matters concerning ground equipment and a unified method of using them?

The CHAIRMAN: The meeting had tried to deal with a subject which had so many ramifications that it had only been possible to skim over very many details which they would have liked to have gone into much more deeply. For instance, the subject of

economics alone was worthy of much closer attention than had been possible on this occasion. Consequently, he had asked the President of the Society whether, when everybody came back from America, it would be possible to have another similar meeting in which to roam over the whole field, with the subject subdivided up into sections. He was very keenly aware of the fact that in these days of war many people could not disclose or even discuss interesting developments which were hidden by virtue of national safety. That was one of the handicaps of having a discussion at the present moment. Nevertheless, he thought the meeting had been fruitful and he was very conscious of the fact that another meeting would be desirable. He hoped the President would be able to allow such a meeting to be held and no doubt he would make an announcement with regard to it later.

Dr. ROXBEE COX: Invited by the Chairman to continue what he was saying when he was interrupted to allow Mr. Hildred to speak, he said there was not much more he wished to say. Reference had been made by a previous speaker to the necessity for low load drag and for reducing the drag coefficient. This was, perhaps, a small point, but it would be very desirable to have some other basis because drag coefficient was unsatisfactory, depending as it did to such an extent on wing loading. The best criterion, in his view, was the drag per unit of weight. It might even be the drag per unit of pay load or per unit of disposable load or something of that sort; some better criterion could, he was sure, be arrived at if the question was studied intelligently. It was clear that if one compared a very highly loaded type of aeroplane with an all-wing aircraft, something rather than drag coefficient was needed.

The other point he would like to comment upon was with regard to what had been said on the undesirability of building a complete power plant equipment and just dumping it into the aeroplane. To get the low drags, which he believed were generally agreed to be essential, it should be possible to design the engine and airframe as a whole, with the engine influenced in its shape and disposition by the requirements of the structure and aerodynamics, which in turn were influenced by the nature of the engine. That had been brought home very much to some of them in recent years by consideration of the proper exploitation of the gas turbine. There were so many variations possible that, in any given instance, it should be possible to achieve a power plant which not only in power but in sheer geometrical shape was the best adapted to the particular specification under consideration. If work was conducted along these lines there was a chance of bringing the drag tumbling down, and the effect of that would in many designs be even more valuable than it had been in the past because with the gas turbine jet propulsion engine the reduction of drag would make the engine more powerful! Consequently he pleaded for a very careful analysis of the way in which the drag of aeroplanes should be compared.

Mr. GARRARD: With reference to the initial cost of aircraft, he assumed two machines, each weighing 55 tons and having the same operating plant. Due, however, to variable factors, one of the aircraft cost £150,000 and the other £200,000. Therefore, the more expensive plane had to earn amortisation over a period of, say, five years on an extra £50,000, or £10,000 per annum. Assuming the aircraft did 100 round trips of the Atlantic per annum, to pay for the extra capital charges it would be necessary to carry only one extra passenger at £100 per round trip. Thus the initial cost was closely related to the efficiency of the aircraft. Looking at the matter another way, was it economical to spend in this case up to another £50,000 to achieve the small saving in weight necessary to carry an extra passenger? He would very much like to have other views

on this point because he felt that the question of initial costs should be put into a better perspective in relation to the pay load an aircraft must carry. In his earlier remarks he had omitted to mention the interest on the extra £50,000, but that did not amount to a great deal in extra pay load required.

Mr. JEFFCOCK: The questions raised by Mr. Hildred called for a full discussion on their own. He proposed to ask one additional question and to suggest ways in which it might be answered. He would like to ask aircraft users and designers: "Have you ever thought whether you personally have any direct responsibility for seeing that you get the right sort of radio services and equipment; do you make a point of keeping in touch with progress in that field, and do you devote as much attention to that part of the design of your aircraft as you do to other vitally important aspects?"

The especial importance of radio in aviation arose from the fact that, in bad visibility, it offered the only practicable means of reaching one's destination without risk of collision, and of landing safely. Because most radio aids involved airborne and ground equipment, world standardisation was essential for international air transport. That could only be achieved through Government channels. At the same time, those concerned with airline operation should play their full and responsible parts in the formulation of radio policy and in keeping their Governments up to the mark.

The outstanding progress of radio development during the war would provide invaluable technique for civil aviation. However, it did not necessarily follow that equipment suitable for civil aircraft would be ready on the shelf when the war ended. Its development might take a considerable time. Meanwhile there might be an awkward gap and that was a matter of direct concern for aircraft designers and potential operators. He urged them to take a more active, direct and personal interest in this field.

The organisation of airlines and of aircraft design concerns to secure the optimum utilisation of radio technique were matters which might well repay careful study, particularly in the light of American practice. His question should also be considered by the Royal Aeronautical Society, which could, itself, make an important contribution by pursuing a policy designed to keep its members in touch with aeronautical radio progress.

Mr. WOODFORD (Associate Fellow, English Electric Co. Ltd.): Civil aviation, to be successful, must sell passenger amenities, and most of the things contributing to that would have some cost in pay load. A great deal had been heard of regularity, but convenience was another important amenity. Something had been said about the type of undercarriage to be used, and the added safety and convenience associated with the tricycle type may be held to justify its reduction of pay load. Again, there was the effect of equipment on pay load. The amount of airborne radio equipment, for instance, needed for operating over wide ranges would be much more than that required over the shorter ranges of internal routes, where the ground installations would accurately locate the aircraft and direct the flight and landing under all conditions. A proper consideration of these matters would have a vital effect on the popularising of civil aviation.

The question of starting engines had been mentioned by Mr. Hives, but very few aircraft were dependent on their own battery for starting. There was no reason why the ground equipment should not cater for starting.

Mr. MARSH: Although a great deal had been heard about aircraft design and speed, nothing had been said about the maintenance of aircraft en route. There was little use in travelling over a route at 300 miles an hour and when the first stop was reached having to remain there for five hours to take out

the air speed indicator which had become unserviceable. It was necessary for two mechanics to get into the bowels of the machine to remove it, and that was not economic. More attention should be paid by the aircraft designer to interchangeability of parts en route.

Sir FREDERICK HANDLEY PAGE (Fellow): He was not quite sure that Mr. Chadwick was right in saying that the conventional type of aircraft would hold the field for some time to come. There were certain things which made that extremely difficult to be the case. It seemed to him extremey probable that they would see a change in the type of aircraft that would be made, particularly if jets were used. In endeavouring to prophesy what was likely to happen in the future, he said that when in the early days the old biplane was used, it had a cruising speed of 100 to 120 miles an hour, and that was conditioned by the drag appropriate to the particular type of vehicle.

As machines had become more efficient and the drag less, higher cruising speeds had become possible, and at these higher cruising speeds it was worth while incorporating retractable undercarriages and variable pitch propellers. Looking forward, could it be said there would come into being other factors which would help to reduce drag, and of which full account could be taken so that a cruising speed of 300 miles per hour could be maintained? Unless there was something in the bag by way of reduction of drag, etc., he could not see that cruising speeds would be substantially increased.

There were, he thought, two things one might consider: one was laminar flow wings and the other was jets, and what had to be thought about was the manner in which these would basically affect design so that it would be economical to cruise at 300 miles an hour. A forecast of drag reductions possible from known developments would enable cruising powers to be calculated, and with these figures of cruising power one could see how new developments fitted into the picture, whether for long range work initially heavier power plant weight was balanced by more economical consumption, or whether for short range a lighter initial weight offset a higher consumption. It is quite evident that at a cruising speed of 300 m.p.h. it would be worth while having added complications in the design to reduce drag, which would not be worth while at lower cruising speeds, just as retractable undercarriage and variable pitch propeller were worth while at 200 m.p.h. but not at 100 m.p.h. cruising speed. There would have to be considered the proper time to introduce this higher cruising speed, and, finally, it would be necessary to overcome the innate conservatism of the ordinary pilot, and also that of the passenger.

Whereas in wartime the rate of accident due to the introduction of a new type might not have an adverse effect on a new design, in peacetime one good crash on a new type of aeroplane would have a very adverse effect on the ability to sell that type to a conservative customer. Of all people who bought things, the most conservative was the air passenger who entrusted his life to a particular aeroplane, and in that respect, added Sir Frederick, he was as conservative as anybody!

The PRESIDENT (Sir Roy Fedden): Before the proceedings closed he was sure everybody would like him to say how fortunate the Council had been in getting Lord Brabazon to act as Chairman of this meeting. In cases of this sort everything depended on the manner in which the Chairman handled the proceedings and, at the same time, kept to schedule, and personally he wished to thank Lord Brabazon very sincerely for the way he had handled the meeting.

He would also like to thank the speakers who had come along and given such interesting talks which had led to valuable discussions. Like Sir Frederick Handley

Page, he was a little sorry that the future had not been dealt with more fully. In his view the whole technical side of civil aviation needed to be discussed on a long term basis. At the same time, both Mr. Hives and Mr. Roy Chadwick had been thinking of filling the bill for the immediate future and had made some suggestions which promised interesting developments for civil aircraft after the war or at some future date.

The Council of the Society had set their hands on endeavouring to create interest in discussions on civil aviation, and he looked upon this first effort as really a good one. One behalf of the Council he could say that early in the New Year they would certainly have another meeting.

Selection and Training of Personnel

Mr. R. ASHTON (Associate Fellow) (*contributed*): Before the war it was impossible to become an airline pilot unless a considerable sum of money was spent in training either by the aspirant or by the Government in training him through the R.A.F. or R.A.F.V.R. The tendency was therefore to make the career that which could be followed only by a certain section of the community. A remark was made that in the future one might expect to hear of cases of boys who would run away to the air as occasionally happened before when they ran away to sea, and it is not such a silly remark as it sounds because it should be possible for a young man to start in the aviation industry and by service and without cost to himself work his way through the various grades until he becomes a qualified captain of aircraft. In the past it has been thought necessary to give definite courses of flying instructions, but if a young man, being a member of an air crew, spends a number of years gaining experience, it should be possible for him to learn to fly on the job without risking the aircraft in the slightest.

With flying itself it would appear to be desirable for there to be a definite course of instruction on landing and take-off, but it seems that one might be looking at flying training from only one angle. The angle of learning to fly as a member of an air crew has never been properly explored. It is true that learning to fly this way would take considerably longer, but there is also some considerable advantage in learning to fly large aeroplanes slowly instead of going through what is after all nothing but a concentrated course of instruction. He suggested that the sequence of events should be Ground Engineer, Flight Engineer, 2nd Pilot, 1st Officer, Navigator, Captain. There is no reason why the large airline companies should not have their own special schools, and these schools should be able to give instruction at each stage in the career of a prospective captain of aircraft.

A similar career but entirely devoted to the maintenance and service of aircraft and engines could be also arranged for those who have no aspirations to fly but are interested in the purely engineering aspect, and a third career could also be laid down for those who were most interested in the commercial and passenger handling side of an airline. If they are to get the best airlines in the world, it is essential that the industry is open to all and not only to certain sections of the community. One of the major difficulties would be the availability of suitable instructors, and in the case of the College that is proproposed he considered that that will be their major problem.

It is true to say that at present, and possibly for a few years after this war, the industry will recruit most of its pilots and air crew from the R.A.F., but in the future he thought that the industry should have a scheme such as that outlined above, whereby it will be able to supply pilots and other air crew from within itself. General Critchley said that 95 per cent. of accidents were caused by pilots, and then qualified this remark by stating that a case had occurred where a pilot had failed to check that his radio was properly secured. As far as he could recollect there are no figures

published in this country or America showing anything like that percentage. It is possible to argue that every accident is caused by a pilot because he fails to extricate the machine from the difficult position in which it is before the actual crash; but this can only be a secondary cause of any accident, and the primary cause can be any one of a number of different things such as the failure of the radio equipment or the failure of any other vital part of the aeroplane on which the pilot is depending.

Economics of Air Transport

The type of freight likely to be carried by air transport could be mail, express goods and such other freight that would be spoiled or would be deteriorated in value by time. For instance, although Major Thornton mentioned a certain type of fish, it is true, nevertheless, that there is a very large variety of articles which can be carried by air, and by air alone; for instance, reference was made later to the carriage of lamb by air which would not therefore be frozen to the same extent that it is at the moment; but there is a very large variety of fruit which is picked unripe and ripens during the sea voyage. This class of goods could be delivered by air and would be considerably improved by remaining unpicked until practically ripe. He thought that it was true and agreed with Major Thornton that air transport will gradually build up for itself the carrying of freight of an entirely different class to that carried by sea. He could not agree that the costs can be split up, since for the purpose of earning a living the air transport company has to show a profit, and if goods are to be collected at source and delivered to the consumer, the total transport cost has to be borne in mind. From an academic interest point of view it is probably right to compare the cost of actual air transport with the cost of transport by any other means.

At the present moment a high safety margin of fuel and oil is carried in aircraft and therefore seriously affects the pay load. The generally accepted figure is that of a safety margin of 25 per cent. of the fuel to be burnt, but there are some cases, particularly the case of short hauls where a 25 per cent. margin is unnecessary; but there are other cases where a 25 per cent. margin may be rather hazardous because of the potential difficulties on a particular air route.

One partial solution is that air navigation should be much more accurate, and by this he meant that there should be a very high degree of similarity between the pre-flight plan and the air navigation log. There certainly is plenty of room for improvement in the flying of aircraft to accurate schedules. The result of accurate flying of this sort would mean that the amount of fuel required for a flight would be known and the safety margin could be correspondingly reduced. He considered that the safety margin at which to aim is one hour or 5 per cent. of the total estimated flying time, whichever is the greater.

Civil Aircraft Design

At the present moment this country is concerned with designing civil aircraft in co-operation and in competition with America, and they had therefore a far from clear attitude regarding basic design characteristics, for, *e.g.*, before the war Great Britain was a signatory to the International Convention for Air Navigation, 1919, and certain elementary conditions are laid down in one of the Annexes to that Convention. Their own air regulations were formed so as to comply with the I.C.A.N., and they found that according to one of the leaflets in the Air-Worthiness Handbook for Civil Aircraft, A.P.1208, the conditions for take-off are that the maximum permissible weight will be that weight which from standing at rest can be carried to a height of 20 metres on a run of 600 metres, and thereafter continue at a rate of climb of not less than 100 metres per minute for the next succeeding three minutes. This country is still a signa-

tory to that Convention, but the U.S.A. is not, and there is some sort of bi-lateral agreement between the U.S.A. and this country.

There are aircraft being designed at the moment and there are designs in project with all sorts of special conditions applying to their take-off, and it seems to me that it is quite impossible to compare aircraft unless they are all designed to the same basic characteristics.

Another effect of this hazy situation is that to some extent civil aviation thought is being affected by the R.A.F. use of overloaded aircraft, and whilst this for military purposes is an absolute necessity, from a civil aviation point of view it is a serious crime. It seemed to him that they must as soon as possible agree with America on basic characteristics on which all aircraft are to be designed. From the passenger-carrying point of view it is essential that an aeroplane so used is able to continue to take off from the worst possible situation if one engine should fail. The design of passenger machines to any other specification other than this is pure commercial suicide.

Reference was made to a streamline shape and Mr. Grey quoted the cases of the Liberator and Fortress, but the most important point which must not be forgotten is that the streamline shape for an aeroplane is not the visual shape, neither is the streamline shape the same for all speeds. In the past they have tended to consider that the shape of the machine is that which can be seen, but from the point of view of drag and speed the shape is that shape which moves through the air and would consist of the visual shape augmented by the various areas of dead air and turbulent air which are carried along with the visual shape. He considered that insufficient thought has been given to the shape of the body which is moving through the air, and they are unlikely to get down to consideration of streamline shapes until they changed their viewpoint.

Civil Aviation Engine Design

During the war serious thought has been given to the construction of power plants, but up to recent years the aero engine designer has stopped short when he got outside his engine and the installation of the various auxiliaries on the bulkheads of the nacelles has not received the same careful attention to design as has been used in the engine design. They should centre on building engines to do a job of work of providing the thrust whether they are reciprocating, gas turbine or jet, while the driving of other units should not be a function of the engine which is providing the thrust. It should then be possible to design power plants which could be installed or changed quickly.

From the operation of the power plant point of view it is very desirable that the control should be single lever and automatic so that the engine provides the maximum thrust for the power output. By engine he also meant that the propeller is included in the term engine. In the case of aircraft with multi-engines it is desirable that there is an automatic balancing unit which would automatically balance all the engines. At the present moment one look at the back of an engine when installed in the nacelle makes an engineer wonder how the whole thing is put together, and whilst the fitting in of the various pipes, control rods, levers and wires may be extremely ingenious, the whole is unnecessarily complicated and from a maintenance angle is a nightmare. If all the auxiliary units are removed and are operated by a small motor in the fuselage and the controls, etc., are then simplified and brought to a standard position on the nacelle bulkhead, then it would be infinitely easier to maintain the power unit.

Route Facilities

Radio

A speaker wished to impress on radio manufacturers the need for a determined line regarding the class of radio required

and an early consideration of radio in the design of an aeroplane. He thought that specifications for radio could be laid down as follows:—

(*a*) That radio must be able to operate with 100 per cent. clarity in all atmospheric conditions.

(*b*) Where radio is used for position finding either from the ground or the air it must be possible to determine the position line with an error of less than one quarter of a degree. Where position is given by the use of one or more radio stations it must be possible to give the position to within one quarter of a mile at a distance of 100 miles from a base line joining two of the stations used. These conditions relate to communication and to general navigation.

When the special use of radio for approaching an aerodrome and landing are considered, it is then essential that radio must be capable of defining with extreme accuracy in three planes because it must be possible for an aeroplane to land and take off under the worst atmospheric conditions with visibility reduced to zero. In the case of landing and take-off it must be possible for the pilot of the aeroplane to determine instantly his exact position relative to the runway, and to the ground to within two feet.

All radio should be robust and capable of standing up to long periods of use without failure, and must be easy to maintain. Finally, the initial and maintenance costs must be low. These conditions would appear to be extremely stringent, but transport aircraft carrying passengers cannot accept less, and the problem of design must be left to the scientists and radio manufacturers. There are two main sides to the radio; one is ground operation and ground stations. These should be supplied by the State and that all countries should operate the same type of equipment. Radio sets used in the air should be supplied by the operator of the aircraft and must be such as will fit in with the ground stations.

Aerodromes

The question of size of an aerodrome is closely related to civil aviation design since it is possible in theory to ask for extremely long runways to permit the use of aeroplanes with very high wing loading, but as mentioned earlier, the basic characteristics of aircraft design must be laid down and consequently the length of runway for even the very largest aeroplane will be standard.

A runway of 5,000 yards should be the maximum required, otherwise the cost of aerodromes will become prohibitive. Aerodrome control is an extremely important subject and it is essential that all airports use the same form of control. The criterion in this case is the continuance of all services under the worst atmospheric conditions with zero visibility, and any instructions or routine to be followed should then be designed with these conditions as their base.

Meteorology

The meteorology facilities should be provided by the State since aviation meteorology is only a branch of the main subject. It is essential that accurate forecasts are made available and he suggested that the taking of observations and the relation of these observations to sea level is discontinued as soon as possible, and that instead observations are made at gradient wind level—that is, at about 1,500 feet. This might mean that radio-sondes are used, but it seems to him essential that a level of the atmosphere must be used as a basis and not sea level, and that they should forecast vertically upwards and downwards from that level.

At the present moment, observations are made at sea level, but any particular place will have a mass of variants which will upset the expected behaviour of an air mass, so that considering statistical facts it is impossible to identify the air mass by the characteristics which are shown at ground level. He was advocating gradient wind level since it is at this level that the wind bears the closest connection with the isobars. If

this had been the practice in the past, they would have been much further forward in the science of long-term and short-term forecasts.

Education

Lt. R. C. ABEL, R.N.V.R. (Associate Fellow): The influence of aviation on every other human endeavour is so great and is increasing so rapidly that all this development of training will in reality be the development of a new era in which not only will aeronautics as the *highest example of the engineer's art* take the lead.

He made a triple suggestion: (*a*) Arrangements between polytechnics and aircraft factories of all kinds, either for evening-class co-operation, or sandwiched whole-time courses, or some other arrangement copied from other branches of engineering; (*b*) formation of many more schools, such as the de Havilland Technical School seems to have developed into, with orthodox constitutions; (*c*) federation of all this about a post-graduate research centre—a suitable constituted college.

The kind of training advocated by General Critchley would find a place in this federation as a sort of Empire Science College which has been very much urged in some quarters for the teaching of Empire geography and history and kindred subjects, so essential to correct behaviour and tactful opportunism in officials in out-of-the-way places.

The centre of this federation would be the College of Aeronautics, and they ought to have such great hopes of attracting students from all over the world.

Among various dispersal schemes for post-war London the main Colleges of the University of London might very well move outside London, so leaving an additional large number of polytechnics free to join with other polytechnics and colleges all over the country in a very comprehensive scheme, perhaps even spreading outside this country. University status might be obtained by the federation by regional affiliation of its component colleges to the various recognised universities.

Such an arrangement is particularly important for the aircraft industry since it will inevitably be a sort of top-heavy industry with its design personnel relatively very numerous compared to the production side. The numbers of air liners likely to be required will be so small that there will be no real " mass production " and new types will be constantly introduced with " trickle" replacements.

This does not imply that design personnel will be poorly paid, though that has been so in the past. On the contrary, the relatively few aircraft will bring a rich return by virtue of the frequency of their trips. Nor will the design personnel consist of an unpractical type of draughtsman, but rather an engineer type, since full scale lofting will be the system of design once the general layout is decided on the drawing board.

Economics

The fundamental difference in character between the airlines of the United States and the British Empire is that the former are densely compact, while the latter are long and spidery. The great ocean airlines of the U.S. have grown from the densely compact routes. Different companies operating British long routes would find too little traffic to justify the long range organisation, and so they keep on collapsing to the unsatisfactory " chosen instrument " policy.

The solution seems to be that the shipping companies with all their established organisation should be considered the natural operators of airlines. At the same time a very close partnership between the Ministry of Civil Aviation and the Board of Trade would be built up, and herein lies the true importance of the Cabinet rank of the new Minister.

If the railways are really keen on running a metropolitan air service as it were, then let them do it through their subsidiary ship-

ping companies rather than introduce complications with the Ministry of Transport, if nothing worse.

The second fundamental point under economics is the inevitable necessity for the world sea and air transport belonging to the United States and the British Empire to be brought under a unified control of a strictness acceptable to and appointed by all the governments of the group. The British members of this body should be appointed by the Ministry of Civil Aviation and the Board of Trade.

A restored Dutch Empire might very well be included in such a union which, based on sea law, would in fact be the only international constitutional development in the world—its roots going back not only to the second or third century B.C., but most profusely to the seventeenth century A.D., when the Dutchman, Hugo von Groot, wrote his famous book on the international law of the sea.

In the nineteenth century a great deal of development of these laws was brought about by Great Britain and the United States.

Design

It has been generally admitted that the development of aviation was greatly accelerated by the last war, although too much emphasis was placed on higher-powered engines rather than efficient design. This distortion was no doubt put right in the ensuing period of commercial development, and this war has had quite a different effect. Although the emergence of jet-propulsion may be regarded as analogous to the emphasis on higher-powered engines, yet the most vital development is that aviation is dividing into two different techniques—military and civil.

The first consists essentially of aircraft to withstand great accelerations, such as fighters and flying bombs, which, if scientifically developed in various details, will inevitably replace the piloted bomber altogether.

The other technique comprises the liner type, which is convertible to certain war uses, such as troop transport and anti-submarine patrolling, but not bombing or fighting, since the design is fundamentally different.

Considering this division of technique in another way, a future more mobile Royal Navy might be considered the natural operators of catapulted flying bombs and fighters, the latter not only from ships but from temporary airfields, for which the complete equipment must be transported about the world by ships enjoying command of the seas. At the same time, the third service would be essentially a mercantile service of ships and flying boats, convertible as always to war duties, so that civil aviation would be mainly concerned with large aircraft and aircraft for club flying activities.

Sir Henry Tizard's proposal for aeronautical research under the Lord President of the Council brings up the question of the effect of the R.A.E. on design generally, and the division of technique just described has an interesting bearing on this, and might lead to the conclusion that a revived R.A. Factory should specialise in flying bombs.

Routes

The way to make a route a British route is to provide the facilities on it because an aircraft is not a denizen of a new third element, any more than a grasshopper. It would be interesting for some big airline company to state what proportion of the life of an aircraft is spent flying—he believed 20 per cent. is a maximum figure. Moreover, the meteorological and radio facilities on a route are absolutely indispensable for reliable operation of services.

Too much emphasis cannot be placed on what might be called the " occupation " of the routes by maintenance and navigation services, and here again the shipping world provides a prepared organisation, not forgetting the help obtainable from ships en route.

The use of rockets for meteorological

purposes has been the dream of rocket enthusiasts for a great many years, but he was afraid only as a finance-attracting stepping stone towards the space-ship, and this attitude has always made the practical suggestions too complicated.

One might reasonably hope that another effect of this war will have been the development of rockets of a simple and almost foolproof nature sufficiently powerful for the altitudes useful for meteorology, though probably developed along quite the wrong lines to be embryo space-ships.

He could not see any adequate reason why a daily or even thrice-daily three-dimensional meteorological map of the whole world should not be produced by a properly equipped and organised service using aircraft, ships and bases all over the world. These maps could be printed at every aerodrome from telegraphed data and made available to all who need them.

Mr. R. M. CLARKSON (Fellow): Dr. Roxbee Cox rightly drew attention to the disadvantage of ton miles per gallon as a measure of commercial efficiency in that it places no premium on speed as such, but his suggestion of ton miles per hour as an alternative is open to objection. Ton miles per hour being the product of pay load and miles per hour is a measure of earning capacity per unit of time, but it does not tell them anything about the efficiency of the earning ability of the vehicle; for instance, large aeroplanes naturally show higher values of ton miles per hour than small ones, but they are not therefore necessarily any more efficient. If, however, they divide ton miles per hour by gallons per hour they immediately got ton miles per gallon or earning capacity/fuel cost, and since in the aeroplane fuel cost amounts to almost 50 per cent. of the direct operating cost of the vehicle, the result is a rough measure of earning capacity/operating cost or commercial efficiency. Ton miles per gallon is therefore, from the commercial point of view, a very good index of efficiency; also it is an excellent criterion from the aircraft technical viewpoint because it embodies in a nutshell, as it were, the three component efficiencies of the aeroplane: structural, propulsive and aerodynamic (*i.e.*, pay load/total weight, specific consumption and L/D). It is in fact the best of all simple criteria of commercial economy. The fact that ton miles per gallon places no premium on speed is in many respects an advantage; it simply measures the cost of transportation with no reference to the speed at which it is achieved, and can be generalised and applied to any form of transport—land, sea or air—by merely replacing "gallons" by B.T.U.s or horsepower hours.

It is for the operator or, better still, the travelling public to place a value on speed; when this is done it is easy to multiply ton miles per gallon by some function of V to give it a speed bias. For example, let it be supposed that a passenger who is willing to pay 3d. per mile to travel in, say, a D.C.3 at 175 m.p.h. will pay $4\frac{1}{4}$d. to travel at twice this speed, and $5\frac{1}{4}$d. at three times this speed, then the multiplying factor to ton miles per gallon to give it the appropriate speed bias is $V^{\frac{1}{2}}$, and the modified efficiency factor might be written:

$$\text{Ton miles per gallon} \times (V/175)^{\frac{1}{2}}$$

The D.C.3 achieves 5.5 pay load ton miles per gallon at 175 m.p.h.; aeroplanes cruising at higher speeds than this would need to achieve the following ton miles per gallon in order to be equally efficient on the criterion:

Speed m.p.h.	350	525
Ton miles per gallon ..	3.9	3.2

If it is assumed that the value of speed is directly proportional to the speed instead of to its square root as assumed above, then the required ton miles per gallon would be 2.75 and 1.8 respectively; *i.e.*, if somebody will place an economic value on speed, it is then easy to evolve a criterion with a ton miles per gallon foundation which will express the

relative "payability" of vehicles at different speeds.

Speaking as an aerodynamics man, amongst other things, he should be the first to agree with Mr. Grey that they knew little about aerodynamics, but they would know still less if it were not for the research workers whom he despises. His mystery about the aerodynamics of the Liberator and the Fortress seems perfectly clear: all good aeroplanes are to some extent a compromise, but one requirement generally takes precedence over all others; in the Liberator it is range, and in the Fortress armament; he did not know of any two qualities for which the aerodynamic requirement is more at variance.

He would like to endorse the remarks of Mr. Peter Masefield and others regarding speed, its importance and cost. The aeroplane is essentially a vehicle of speed; it can more easily take advantage of technical developments in the direction of more speed for the same cost rather than less cost at a given speed. The history of air transport over the past, say, fifteen years or so proves this. It would be impossible to design an aeroplane now incorporating all the technical advances which have become available since the H.P.42 and give it much reduced operating cost at the same speed, but the alternative is easy and natural to the aeroplane. Operators must not be dismayed at the prospect of rising cruising speeds; they do not necessarily entail increased cost.

Squadron Leader E. HARROP (Associate Fellow): General Critchley's proposals for a centralised training or conversion centre for the primary and secondary education of all personnel to inculcate a common doctrine of air service is a good augury of things to come; as was also his resistance to any suggestion of plurality of British air services operating in competition. However, his suggestion of perpetuating the R.A.F. short service commission is open to severe criticism. It may be a good thing for the civil airline, by providing ready-made cheap labour, but many of these individuals found themselves being thrown up after five or ten years' service unfit for other careers. General Critchley proposes similarly to dispose of the airline pilot after fifteen years' service. One wonders what the London Transport Board does with its worn-out bus drivers who also have loyally held life (in and out of the bus) in their hands.

These diverging needs for war and peace are a problem, and he suggested that some State *ab initio* flying school should be founded to supply the pilots (for peace or war) by a system of modified conscription, or volunteer reserve, or by selection from the A.T.C. to maintain an adequate establishment of young reserve pilots for all services, both civil and military. Those not absorbed by the R.A.F., the Navy and B.O.A.C. should be kept in flying practice against the needs of war by monthly or annual refresher courses while following some other career.

The remarks of Major Thornton on the absorbing subject of economics were pregnant with matter for untold discussion. One doubts, however, whether the terms open subsidy or concealed subsidy can ever be properly defined. For example, how much is an airline assisted by State provision of meteorological services, "aerial lighthouses," airports (and with what facilities), by free statistical data obtained from staging 1,000-bomber raids, by the availability of R.A.F. short service pilots? What should be provided out of public funds, and how much? They may not all wish or afford to fly, but they all may wish to benefit indirectly from air transportation, by eating strawberries out of season, or by seeing up-to-date news reels of Honolulu on a foggy November evening in London. Is a short term or a long term policy to be adopted, thereby determining the slope of the curve of increasing dividends over the years ahead?

Mr. Chadwick lightly dodged the icing problem, but he doubted if the future

passenger plane will be as agile. Dr. Warner has told them that it is a greater menace than fire in the air. Is there no satisfactory method of combating this danger if they are to fly in all weathers over the Atlantic? Is not the employment of engine exhaust gases to heat leading edges directly or by steam possible?

It was gratifying to hear from Mr. Hives that the military engine is fully adaptable for civil needs, yet one doubts the converse, having in mind the evolution of American air-cooled engines bred on civil operation. Is it because he expects more use of the possible peak outputs (obtainable from military engines) at take-off with the promised higher wing loadings of civil aircraft? Also he did not tell them whether a better fuel should be carried to take full advantage of high boosting for take-off, or whether an inferior fuel for 50 to 60 per cent. power cruising is to be recommended. Although Mr. Hives produces the power plant from his basket of plums, it may be argued that the power plant is a mixed blessing from the economic standpoint when the wear and tear of auxiliaries is not running parallel with the prime mover.

Dr. Roxbee Cox's timely slaying of the jet-propulsion bogey, *i.e.*, uneconomic fuel consumption, was a welcome rejoinder. Some new criteria of effort for fuel expended is obviously necessary.

Mr. Hildred's question of what should be the ratio of airborne equipment to ground equipment—how much should the aircraft be self-contained at the expense of pay load?—can surely be found by a process of elimination and confined to the pilots' needs for safe take-off and landing. Statistics show that 85 per cent. of accidents are due to errors of judgment on the part of the pilot—60 per cent. during the landing approach—from which it would appear that any technical aid or relief to the pilot for assisting him at these periods should be embodied in the aircraft.

Dr. Warner put the case as follows: "In stressing the importance of improvement in operating conditions and mechanical aids, I do not want to underestimate the human factor. The highest possible order of ability, the maintenance of untiring vigilance by every individual engaged in air transportation, and the existence in every individual of a personal sense of responsibility for the success of the whole operation, are absolute fundamentals. The best hope of reduction in that considerable proportion of accidents which are ascribable to errors in judgment or in technique does not lie in further improvement in the quality of the personnel concerned, however, but in reducing the difficulties of their task. If a number of people were given the task of following a 2-foot wide footpath without falling off, the percentage of personal error would be infinitesimal; but if the 2-foot width were reduced to a 2-inch plank and raised to a considerable height above the ground, the number of errors would become large."

In other respects it is absurd to proclaim that the aeroplane must fly by itself when it is so dependent on a paraphernalia of ground equipment ranging from airports to flashing beacons. Moreover, in order to keep the aircraft in the air as much as possible, terminal airports should be provided with docking facilities for simultaneous major repair or inspection of all aircraft detail, and staging posts equipped with full and adequate servicing and maintenance requirements. The maintenance aspect becomes increasingly important as the size and cost of the aircraft increases; so also will the maximum utilisation of aircraft be demanded by the operator. The figure of 3,000 hours per year per aircraft can probably be stretched to over 4,000 hours by effecting a quicker turn-round of aircraft with properly planned and organised ground services, which together with Mr. Hives' engines giving 100 per cent. reliability between 1,000-hour overhauls will allow the aircraft to spend only half its life on the ground.

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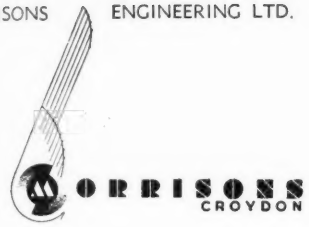

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British Aluminium Co. Ltd., The	Salisbury House, London Wall, London, E.C.2	*Clerkenwell* 3494
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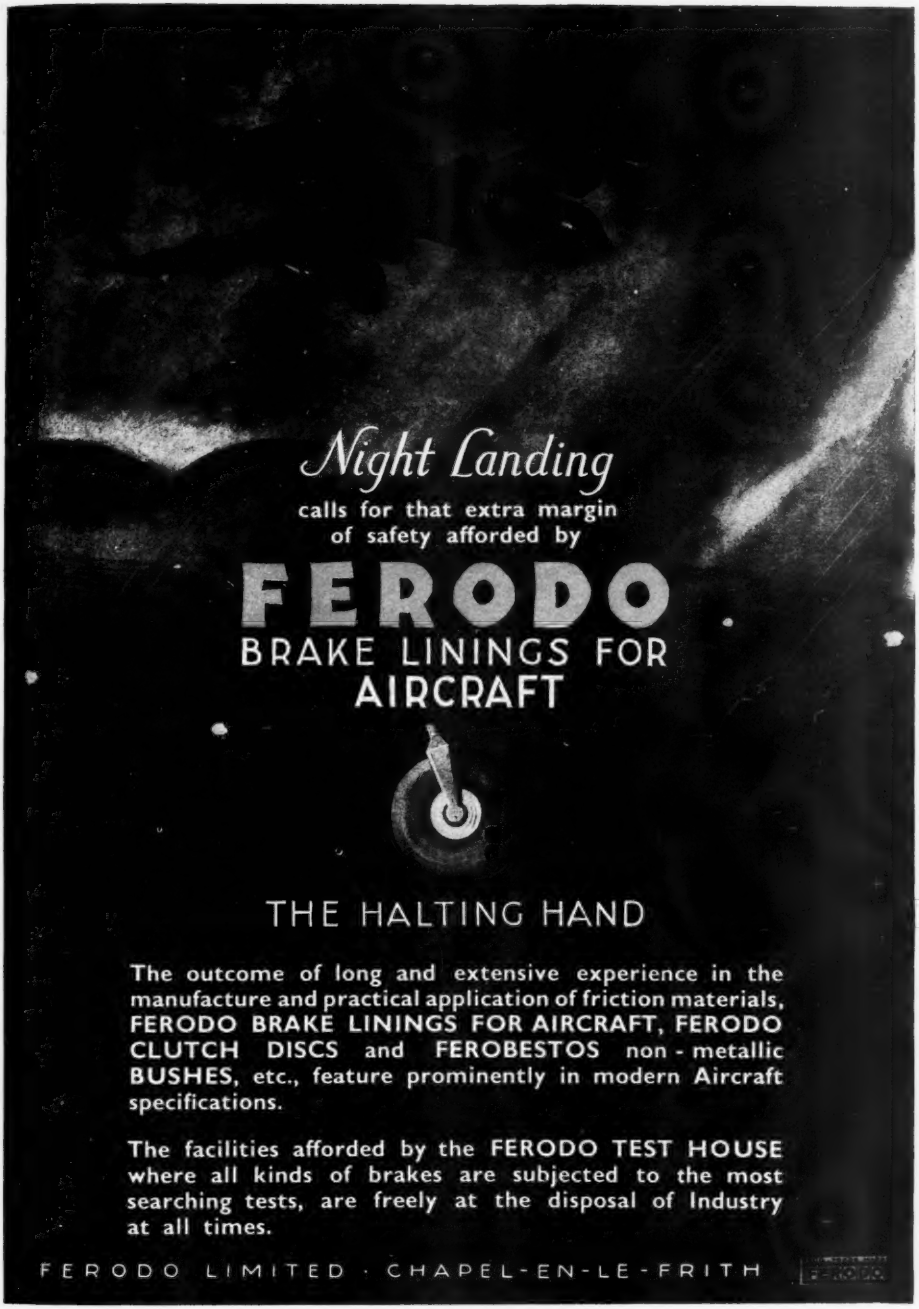
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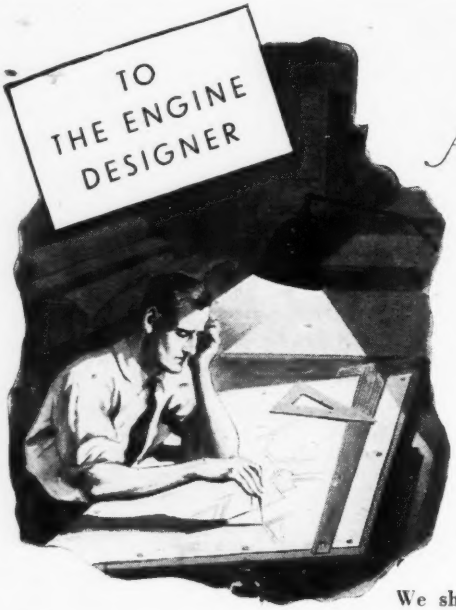

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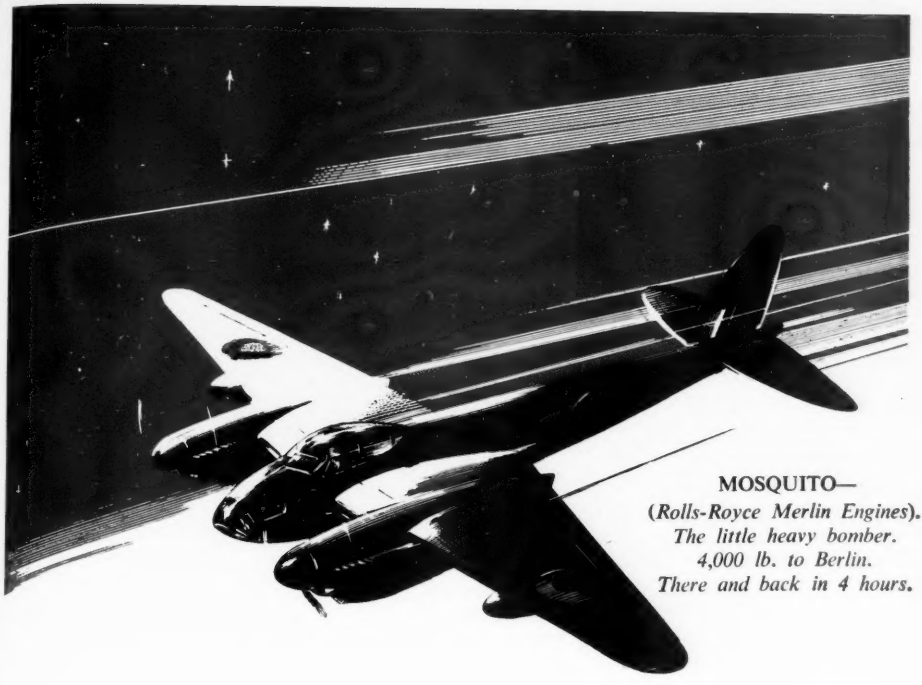

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